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ABSTRACT

Assessment and evaluation of the current 2- and 4-year programs in engineering technology education was the major purpose of the American Society for Engineering Education (ASEE) in authorizing the present study. The study was implemented primarily through a series of conferences involving engineering educators, engineering technology and junior college educators, employers, personnel managers, representatives from professional societies, and knowledgeable laymen. This report of the study includes chapters concerning: (1) history, traditions, and transitions of engineering education; (2) abstracts and 3 important reports on engineering technology education since 1960; (3) recent trends in engineering education and engineering technology education; (4) goals, objectives, and broad features of engineering technology education; (5) characteristics of associate degree curricula engineering technology; (6) desirable characteristics of associate degree engineering technology curricula; (7) characteristics that differentiate between baccalaureate education in engineering, engineering technology, and industrial technology; (8) survey of current baccalaureate engineering technology programs; (9) desirable characteristics of baccalaureate engineering technology programs; (10) practical engineering versus engineering technology programs; (11) human source material for engineering technology education; and (12) assessment of strengths and weaknesses of engineering technology education. (HS)

Engineering Technology Education Study

Final Report

American Society for Engineering Education
January 1972

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for the
Engineering Technology Education Study

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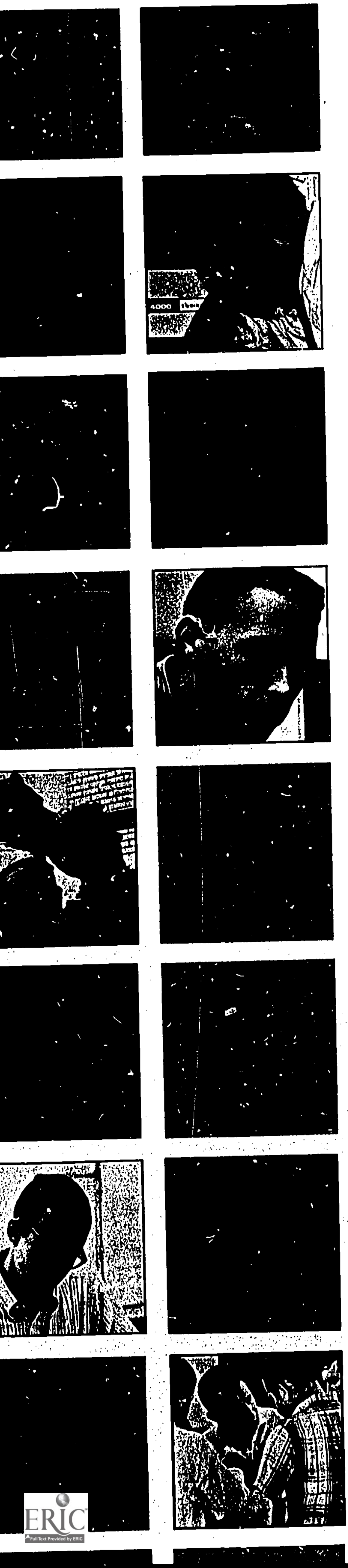

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Foreword

This document, the *Final Report* on a national study of engineering technology education, represents the culmination of more than two years of effort by both the Study Staff and the Advisory Committee. The Report represents the consensus of the members of the Advisory Committee. However, since a large committee cannot be expected to write or edit an extensive report, that responsibility has rested heavily with the staff, primarily the chairman.

This *Final Report* is actually the third major document issued during the study; both a *Preliminary Report* and an *Interim Report* were released earlier. Since these earlier reports were intended for revision, hopefully to incorporate factual information which might not originally have been available and to reflect the influence upon the Advisory Committee of criticisms received, the views of those most closely involved in this study were not presented except as they undoubtedly influenced the body of the reports. In this *Final Report*, however, it seems appropriate to provide the reader with some personal views which may aid him in evaluating the report and in applying it to his particular area of technology. The staff views related to development of future action programs may be of special interest.

Exchange of Information

First, one must be aware that the *Preliminary Report*, when it was issued in 1970, drew more than 200 responses with extensive comments and analyses that greatly influenced the *Interim Report*. The *Interim Report*, on the other hand, drew only a dozen responses when it was published in 1971. Certainly, some controversial statements had been revised, but the change in reader attitude from 1970 to 1971 is believed to be due more to exchanges of information through published articles and conferences where technology education as related to engineering education had been widely discussed. Fortunately, such communications still continue through ASEE, NSPE, ECPD, EJC and the technical societies and are an important mechanism through which this report may achieve useful action.

Specialized Areas with Unique Problems

Other important directions for action are specialized studies by the technical engineering societies and the related divisions of ASEE. The criticisms and comments received on the *Interim Report* focused largely on the failure of the report to treat in detail the relationship of certain engineering technology specializations to the corresponding areas of professional engineering. The relationships with civil engineering and with chemical engineering appeared likely to present troublesome problems. The Chairman has had to respond that the Advisory Committee and the Report could not consider in detail the numerous specialties in engineering technology and their complex interrelationships with engineering. Nevertheless, it is fully realized that no two areas of engineering technology bear identical correspondences to the engineering fields to which they primarily relate. Hence special situations require study and accommodation. To illustrate, we may consider the two specialized areas with unique problems which have already been mentioned.

Example of Civil Engineering Technology

It is clear that civil engineering and civil engineering technology will have different interrelationships than apply in the mechanical, electronic or chemical fields. The civil engineering profession has a much larger percentage of government employment and of self-employment with resulting influence upon related technologists. These interrelationships in terms of the need for and use of technologists, their appropriate education, and the extent of their responsibilities in typical areas of civil employment require study. Such action by appropriate engineering and technological groups is strongly recommended. From comments received, the area of civil engineering technology appears to require such individualized study more than some other areas, manufacturing, for example.

Example of Chemical Engineering Technology

A somewhat anomalous situation obtains in the fields of chemical engineering and chemical technology. Even two-year programs in chemical engineering technology have drawn only a small response from students in terms of enrollments. Apparently the reason is that large numbers of chemistry majors with four-year bachelor's degrees are available for employment at each graduation. Some are employed in chemistry research laboratories as chemical assistants, but others are available for technological jobs which they learn to fill by practical experience supported by their education in science. The Engineering Technology Study could not explore this special situation in detail, but we recommend that appropriate agencies do so and perhaps suggest actions that will provide strong technological support for the field of chemical engineering. Possibly this might be provided through in-service courses for young chemists who need a greater insight into technological operations.

Regional Balance in Production of Technologists

The growth in number of baccalaureate engineering technology curricula and the corresponding applications to ECPD for accreditation of such programs indicate clearly that further development of this relatively young field of baccalaureate education is to be anticipated. If the situation could be handled logically, it would be desirable for each state to evaluate its probable needs and its anticipated production of engineering related technologists, and then take action to achieve a balance. Recent experience with an oversupply of engineers on the West Coast has demonstrated that technical personnel do not move readily across regional lines. Hence one can not assume that an

unbalanced geographical distribution of technological students will redistribute itself for maximum usefulness through employment nationally.

Action Needed by Community Colleges

There is reason for concern that enthusiasm of institutions for moving into baccalaureate technology programs may result in a reduction in the production of associate degree technicians. Those institutions that have had the strongest associate degree programs are, in many cases, logical candidates for establishing baccalaureate curricula. It seems inevitable, therefore, that the major dependence must be placed upon the public community colleges for increasing their productivity of technicians with associate degrees. These institutions need to take seriously their responsibility to provide curricula, faculties and laboratories that would meet the accreditation criteria which have been established for associate degree engineering technology, even if by regulation some institutions are prevented from requesting specialized accreditation. Those that cannot fulfill such requirements should not use the descriptive term "engineering technology" since more applicable designations are readily available. Knowledgable members of the Advisory Committee agreed that a significant fraction of community college technical programs lacked important resources in terms of either faculty or facilities.

Probable Shortage of Engineers and Need for Technologists

This country has been passing through a period of slow growth and in some areas restriction of technological production. All previous experience would lead to the anticipation that a period of much enhanced production lies ahead. Every period of slightly reduced employment of engineers has been followed almost immediately by a period of shortage of engineers. Students seem always to move into an area of education when it is approaching a balance of supply and demand for graduates. For some years the enrollment of engineering freshmen has been either constant or reducing. The fall enrollment of 1971 moved sharply downward in many engineering colleges, especially for freshmen.

Because nearly half of young engineers are completing a master's degree before employment, present engineering freshmen will enter the employment market mainly in 1976-77 when the demand for engineering services seems most likely to be in a sharp upward trend. The opportunity for engineering technologists, both two- and four-year graduates, could hardly be more favorably indicated. The important point to make is that educational institutions, technical societies, accreditation agencies and employers should cooperate in developing their individual action programs so that supply and demand for the total range of technical services related to engineering will be maintained in reasonable balance.

Accreditation Actions

An action taken by the Engineer's Council for Professional Development in October 1971 will carry out the recommendation which appears in this Report that ECPD apply appropriate specialized criteria for accreditation of baccalaureate curricula in engineering technology. Another ECPD action indicated its willingness to accept assignment of the responsibility for accrediting Industrial Technology programs by use of appropriate specialized criteria that would have to be developed through those experienced in this area of technology. Further actions will be needed by technical societies and other engineering groups to develop a consensus of the total profession of engineering that it is vitally interested in aiding the development of engineering related technologies and technologists. Without attempting to dominate the subprofessions it is still the responsibility of each major profession to aid its related or supporting groups to achieve standards of education and experience that will protect the public safety and welfare.

L. E. Grinter
Jesse Defore

January, 1972

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Section 1

Objectives and Procedures of the ASEE Study of Engineering Technology Education

After a series of internal discussions extending over a period in excess of a year, the American Society for Engineering Education made a proposal to the National Science Foundation in March of 1969 that NSF sponsor a two-year study of Engineering Technology Education. This proposal was based in part upon recommendations of an *Inventory Conference on Engineering Technology Education* held January 22-23, 1968, in Washington, D.C. and attended by some twenty-five individuals representing engineering and engineering technology educators, industrial employers, and government and other agencies. In its introduction, ASEE's proposal stated the following objectives:

> This document is a proposal to the National Science Foundation for support of a national study of engineering technology education. Such a study would inventory the current national effort in programs of two to four years duration in engineering technology education, assess the strengths and weaknesses of current educational practice in this domain, and suggest directions for future effort in this area.

As to implementation, the proposal contained this statement:

> It is proposed further that this study be implemented primarily through a series of conferences involving engineering educators, engineering technology and junior college educators, employers, personnel managers, representatives from labor, government and the armed forces, graduate engineers and technicians, representatives from the professional societies, and knowledgeable laymen.
>
> The project will be directed by an experienced educational administrator. Preliminary reports of initial findings will be circulated to institutions, organizations and agencies for purposes of early review and evaluation. This is essential in order that grass-roots participation will be assured and reflected in the final action and implementation of the results.

Based upon this proposal, ASEE was provided with funds by NSF to complete a two-year study of Engineering Technology Education beginning in August, 1969.

Organization and Administration of the Study

The Engineering Technology Education Study was organized and administered as follows:

1. A staff was assembled consisting of the part-time services of two previous presidents of ASEE

and a full-time technical associate with previous experience both in teaching and in administration in institutions providing technical education.

2. Two meetings of an Interim Steering Committee were held for organizational purposes. The activities of this Interim Steering Committee also led to the appointment by the President of ASEE of an Advisory Committee of 24 members; the members of the Advisory Committee are listed on the preceding page.

3. The Advisory Committee has held five two-day meetings. It has received reports prepared by the staff and by subcommittees. Staff members have reported to the Committee on visits to some 50 institutions having either 2-year or 4-year programs in engineering technology. It has revised reports as received to reach a consensus and has reviewed drafts of the *Preliminary* and *Interim* reports at three successive meetings.

4. In October, 1970, the *Preliminary Report* was distributed widely and then more than 2000 copies were purchased by universities, companies, technical societies, and individuals. A request was made for comments and analyses, and some two hundred communications were received. These comments influenced the preparation of the *Interim Report* to an important degree.

5. The *Interim Report* was prepared during the second year of the Study. The objective of distributing an interim report before the end of the study was to maximize the opportunity previously provided through the distribution of the *Preliminary Report* for obtaining feedback including factual knowledge that may not have reached the staff or the Advisory Committee.

6. This *Final Report* has been prepared after consideration of all communications received. The Foreword occurs only in the *Final Report*. It was added primarily to clarify the fact that consideration of the special problems of each area of technology and its special relationships with engineering was beyond the scope of the Study. It is inevitable that some repetition of definitions and characteristics of curricula occur in several sections of this document. This is due in part to multiple authorship but more importantly to the need that the sections dealing with associate degrees be complete and independent of those dealing with baccalaureate degrees because of different readership.

Section 2

History, Traditions, and Transitions

The Beginning of Technological Education

Compared to liberal higher education, the roots of which in the United States reach back to the founding of Harvard in 1636, technological education has a relatively brief history in this country. While almost all of the colonial colleges were by 1750 teaching mathematics and science, frequently including technical subjects such as surveying and navigation under the heading of mathematics, it was not until 1802 with the founding of the Military Academy at West Point that appreciable attention was given to technological education (Brubacher and Rudy, 1958, p. iii).

The world beginnings of modern technological education are only slightly more remote than those in America. The earliest date usually cited is 1766, the year of the founding at Freiburg, Germany, of a technical mining school. Some historians accept 1775, when the French Ecole des Ponts et Chausees opened, or 1794, when the great Ecole Polytechnique was established (Read, 1939, p. 351).

The Development of Engineering Schools

After its tardy introduction to the higher education enterprise in this country, engineering education eventually flourished. Norwich University founded a Department of Civil Engineering in 1819; Rensselaer Polytechnic Institute was founded in 1824; Union College founded a similar department in 1845; Harvard established the Lawrence Scientific School in 1847; Yale, in 1847, began a department which later evolved into the Sheffield Scientific School; and the Massachusetts Institute of Technology, perhaps the most renowned of all the institutions of its type, was established in 1865 (Brubacher and Rudy, 1958, p. 62). The Morrill Act of 1862 greatly stimulated the founding of additional institutions. By the beginning of this century, some 42 engineering colleges had been established. In 1970, a total of 274 engineering schools were identified (Alden, "Enrollments", 1970).

Early Development of Technical Institutes

During the same period in which engineering colleges developed, a second, distinctly different kind of educational institution was emerging also. This was the "mechanics institute." Schools of this type were founded mainly in eastern and midwestern industrial centers, and made their first appearance during the 1820's. These early institutions may be regarded as the precursors of technical institutes. They offered courses in mathematics, bookkeeping, surveying, navigation, and other vocational subjects; they sought the "promotion of the useful arts"; they trained artisans and draftsmen. They attempted to provide training to meet the manpower needs of an expanding industrial economy for draftsmen, supervisors, designers, production workers, and other technical personnel which neither the secondary schools nor the engineering colleges were meeting directly at that time (Smith and Lipsett, 1956, pp. 18-20).

The first of the technical institutes was the Gardiner Lyceum, in Gardiner, Maine, established in 1822 (Wickenden and Spahr, 1931, p. 4). This school, however, ceased to operate after ten years. Most of the early institutes suffered a similar fate. Only one, the Ohio Mechanics Institute, established in 1828 in Cincinnati, is still in existence; it operates now under the name of the Ohio College of Applied Science. The spread of free public education was cited as a cause for the rapid waning of interest in these schools (Smith and Lipsett, 1956, p. 19).

Later Interest in Technical Institutes

Later in the century, a revival of interest in technical institutes occurred, due largely to spreading industrialization. Spring Garden College, still in existence, although renamed, was founded in 1851 in Philadelphia. Pratt Institute, Brooklyn, New York, was established in 1877 as an institution of this type, but it gradually changed into a traditional engineering school. According to Graney (1965, p. 9), there were "dozens of such institutions started during the late nineteenth and early twentieth centuries." These "flourished for a period of time and then disappeared from the scene." Graney characterized these institutions as follows:

> They geared their instruction to the maturing technology of the time, laying emphasis upon application with intensive instruction during short periods of less than four years. If they tended to prepare artisans, at least to some degree, it was because such artisans as they prepared were qualified, themselves, to bridge the gap between practice and theory.

Development of Community Junior Colleges

Community junior colleges, especially in recent years, have made important contributions to the domain of technological education.

Junior colleges first appeared as identifiable institutions during the mid-1800's (Bogue, 1956, p. 2). The stated objectives of the early institutions were to provide lower division university studies for transfer or general education purposes. After 1900 the junior college movement prospered

and the number of junior colleges increased until in 1921 there were 207 such institutions, 70 public and 137 private (Thornton, 1960). Further growth has been rapid as is shown by Table 1. It was in the 1920's that the concept of occupational education as an integral part of the junior college curriculum received substantial acceptance. The number of occupational or "terminal courses", as they were titled, grew from 100 in 1921 to 400 in 1925, 1600 in 1930, and more than 4000 in 1940 (Hill, 1942).

Table 1. Number of Community Junior Colleges and Total Enrollments for Selected Years, 1900-1970[a]

School Year	Total Number of Colleges	Total Enrollment
1900-1901	8	100
1921-1922	207	16,031
1938-1939	575	196,710
1952-1953	594	560,731
1958-1959	677	905,062
1965-1966	771	1,292,753
1969-1970	1038	2,186,272

[a]Sources: James B. Thornton, *The Community Junior College* (New York: John Wiley and Sons, Inc., 1960), Table 3, p. 155; and American Association of Junior Colleges, *Directory/1970* (Washington: AAJC, 1970), p. 7.

Nearly 90 percent of all American community junior colleges now offer occupational education programs intended to prepare students for immediate gainful employment upon graduation. Engineering technology and related curricula are often included in these community college offerings. In 1968, for example, the American Association of Junior Colleges reported that approximately 300 community institutions offered organized curricula in engineering technology or a closely related field. Such technology programs generally lead to the award of associate degrees.

Community colleges also may offer occupational programs which are post-secondary and have a vocational emphasis, but which lead to the award of certificates rather than degrees.

Baccalaureate Technology Programs

Very recently, a new stream of technological education has emerged, namely, four-year baccalaureate programs in engineering technology. While two-year associate-degree technology programs have a history extending over half a century, being associated with both technical institutes and community colleges, the concept of a four-year curriculum is a contempory development. An early allusion to the idea came in 1957, when J. C. Elgin, of Princeton, wrote in *The Engineer:*

> We should expand the numbers of people trained at the technician level. This can be done through the development of the technical institute, by increasing the number of such two-year — or even four-year — technical institutions, and by stressing the recognition by industry as engineer-technicians and engineering aides, of those so trained.

In June, 1965, Harold A. Foecke, then Specialist for Engineering Education with the United States Office of Education, stated that more than sixty colleges were offering four-year technology curricula. A subsequent research study identified 73 institutions which purported to offer baccalaureate engineering technology programs or programs in "an industrial technology closely allied to the engineering field" (Defore, 1966).

A number of forces appear to have encouraged the inauguration of baccalaureate technology curricula. The two-year technology programs at technical institutes are "bulging from within" as more and more subject matter is added to the curricula. And at the same time, there appears to be an "upward push" due to complexity of industrial enterprise about which Grant Venn (1964) has written as follows:

> Now, technology has advanced many occupations on the technical, skilled, and semi-professional levels to a point where they require higher levels of specialization and related knowledge that are best learned within educational frameworks. Manifestations of this upward push are to be found, for example, in engineering, where the two-year engineering technology curricula of today compare in rigor and breadth with the four-year engineering curricula of twenty-five years ago. As engineering continues to become more complex and specialization is delayed, graduate study will become a must for the engineer, and by the same token, it is probable that within the present decade the bachelor's degree will become a must for many technical occupations.

There also appear to be parental, peer group, and societal pressures for individuals to obtain baccalaureate degrees as a matter of personal or family prestige. A related and even more important drive is to obtain an education that is known to provide upward mobility with experience.

Parallel to the development of baccalaureate engineering technology programs is another important movement. Colleges, schools and departments of industrial education and industrial arts have devised curricula which are intended to provide students with routes to industrial employment rather than to teaching. The first of such "industrial technology" programs was reported in 1923 at Bradley University. Currently, 94 are identified (Stuessy, 1970), and more are projected. The relationship of these programs to engineering technology education will be considered later.

Factors Influencing Change

A number of social forces currently appear to be influencing changes in the nature of engineering technology education. Changes in engineering education, trends to extend engineering technology programs to four years, the proliferation of community colleges offering two-year technical programs, the emergence of industrial technology programs from the area of industrial arts teacher education, and changes in the social-technological environment itself are factors which are serving to give new directions for the evolution of engineering technology education.

Another influence for expanding technological programs is the reduced flow of baccalaureate engineering graduates into industry. This flow is being reduced by two factors: first, the absolute number of baccalaureate degrees in engineering has been essentially static for ten years and now seems more likely to decrease than increase; and second, a growing percentage of baccalaureate engineers continue their studies to acquire the master's degree before accepting industrial employment.

Section 3

Abstracts of Three Important Reports on Engineering Technology Education Since 1960 [1]

(A) Characteristics of Excellence in Engineering Technology Education

The present ASEE Engineering Technology Education Study covers both associate-degree and baccalaureate programs. However, since an excellent study on two-year programs was published by ASEE in 1962, entitled *Characteristics of Excellence in Engineering Technology Education*, considerable advantage will accrue from using the results of that study, commonly called the McGraw Report, as background. The following abstract of the McGraw Report seems of sufficient importance to include in this document.

It is the opinion of the Advisory Committee that the standards presented in the ASEE report on *Characteristics of Excellence in Engineering Technology Education*, which have formed the background for ECPD accreditation of engineering technology curricula, have produced a continuous desirable upgrading of engineering technology education. The following quotations summarize the 1962 report.

Purpose and Terminology

This report seeks to develop guidelines and definitions, to suggest minimum standards for selecting faculty and students, and to explore curriculum requirements for both technical and nontechnical areas. To avoid the ambiguity of the term "technical institute curriculum" it recommends the use of "engineering technology" and "engineering technician" to represent the field of study and the practitioner respectively.[2]

Definitions

Engineering technology is that part of the engineering field which requires the application of scientific and engineering knowledge and methods combined with technical skills in support of engineering activities; it lies in the occupational area between the craftsman and the engineer at the end of the area closest to the engineer.

Engineering technology is concerned primarily with the application of established scientific and engineering knowledge and methods. Normally engineering technology is not concerned with the development of new principles and methods. Technical skills such as drafting are characteristic of engineering technology.

Prediction of Educational Level

There has been in recent years a steady increase in the mathematics and science levels of the curricula of both the secondary school and the engineering college. The engineering technician of tomorrow *must* be educated at a higher technical level than he has been in the past. Though it is difficult to accomplish in the short span of two years, there are certain areas (e.g. mathematics, physical sciences, humanistic-social studies) in which the student must be given a broader base than has heretofore been the common practice.[3]

Faculty

Since these curricula are so closely related to engineering, it is equally obvious that a satisfactory engineering technology faculty must contain a substantial proportion of graduate engineers. It is the Committee's opinion that approximately half the faculty members *teaching the technical specialties* should be graduate engineers or the equivalent. A significant proportion of the faculty must have had relevant industrial experience which is reasonably current.

Admission Requirements

The committee believes that a satisfactory engineering technology program should be based upon the following minimum secondary school units:

(a) Three units of English

(b) Two units of mathematics, one of which is in algebra and the other in plane geometry (or the equivalent of these in integrated modern mathematics)

(c) One unit of physical science with laboratory (wherever possible, physics or chemistry)

The student should have acquired this minimum background before entering the engineering technology program itself.

Engineering Technology Curriculum

An engineering technology curriculum differs significantly from a pre-engineering curriculum, which is equivalent to the first two years of an engineering program. The technology curriculum must initiate specialized technical courses early in the program. The following table summarizes the minimum semester hour recommendations of this [1962] report along with an illustration of their possible application to a 72-hour curriculum. The 72-hour program is an example only; many variations are possible.[4]

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[1] Excerpts from a fourth important report, the California State Colleges study of industrial technology *(Industrial Arts/Industrial Technology,* Office of the Chancellor, California State Colleges, February, 1970), appear in Appendix A. Briefly, industrial technology education emphasizes breadth rather than technical specialization, about one-half of the curriculum for such programs being in non-technical studies, including management. The excerpts from the CSC report have been appended to provide background for understanding the real distinctions that exist between engineering technology education and industrial technology education. A more detailed abstract of this important study was included in the *Preliminary* and *Interim Reports.*

[2] These terms have become common usage.

[3] In retrospect it seems that the 1962 report presaged the current movement into engineering technology curricula of four years duration.

[4] The report mentions more extensive curricula up to three years in length.

Mathematics and Physical Sciences

All branches of engineering technology are built upon a foundation of mathematics and physical science. Mathematics is one of the more critical determinants of both the level and the quality of an engineering technology curriculum. The most common criticism by graduates and employers is directed toward the level of mathematical content of engineering technology programs. There is no doubt that the ultimate depth to which the physical science and technical specialties portions of the curriculum can be pursued will be determined greatly by the mathematical preparation of the student.

Recommendations:

(a) Mathematics taught in the engineering technology curriculum should be college level and emphasize problem solving rather than extensive mathematical proofs.

(b) Mathematics should generally be taught in separate courses from science and technical subjects by qualified mathematics instructors familiar with the engineering technology objective.

(c) Enough Calculus should be taught to guarantee that students are professionally literate and to permit use of this mathematical tool in the technical specialties.

If the mathematical sciences underlie all the technical courses in the curriculum, similarly the physical sciences give them unity. Thus, it is to the physical sciences that the engineering technician must look for the fundamental concepts which tie together all the technical areas. Toward this end the courses should emphasize the understanding, measurement and quantitative expression of the phenomena involved. Physical science courses should be accompanied by appropriate laboratories. Careful work, precise observation and accurate measurement and recording should be emphasized.

CURRICULUM SUMMARY IN SEMESTER CREDITS

	*Minimum		Illustration	
Basic Science Courses				
Mathematics (e.g. algebra, trigonometry, calculus)	9		12	
Physical Sciences (e.g. physics, chemistry)	6	15	6	18
Non-Technical Courses				
Communications (e.g. English composition, speech, report writing)	6		6	
Humanistic-Social Studies (e.g. economics, literature, history)	6		6	
Other (e.g. management, human relations, or additional humanistic-social studies)	3	15	3	15
Technical Courses				
Technical Skills (e.g. drafting-basic, manufacturing processes)	6		6	
Technical Specialties (e.g. semiconductors, strength of materials)	24	30	33	39
Totals		60		72

*Institutions should view with concern any curriculum which meets only the minimum shown above. Variations above the minimum are not only expected but desirable.

Non-Technical Courses

An engineering technician's education should include instruction in linguistic communication, humanist-social studies, and other appropriate nontechnical studies. Technicians have expressed the need for better preparation in English and report writing. Engineering technology curricula must educate students not only for immediate employment after graduation but also for subsequent development as citizens and responsible human beings and should whet interest in personal development in these areas after graduation.

Technical Skills

The ASEE *Report on the Evaluation of Engineering Education* (1955) indicated that future engineering curricula would probably show a decrease in the proportion of time devoted to technical skills such as drafting and manufacturing processes. The engineering technician has been expected to move upward to fill this gap. Graphic expression is as much a part of technical language as is mathematics. Every engineering technician should have a first hand knowledge of the general capabilities, limitations, and economics of the conventional manufacturing or construction techniques used in the industry in which he works.[1]

Technical Specialties

The technical specialties or majors, cover such areas as electrical, electronic, mechanical, civil, chemical and construction technology. The technical specialties are always in transition. What today is an innovation in professional engineering tomorrow becomes the established engineering practice falling within the province of the engineering technician. Technical specialties courses should include considerable attention to problem identification and solution and should also emphasize the quantitative analytical approach. Provision should be made for a design project or course in which the student is required to integrate the knowledge obtained throughout the program.

Laboratories and Library

Theory courses in the technical specialties should be accompanied by coordinated laboratory experience which stress measuring physical phenomena and collection, analysis, interpretation and presentation of data. Students should be reasonably familiar with the types of apparatus that they may encounter in industry.

Use of the library is essential in all forms of higher education. The library supporting an engineering technology program should be one which will encourage the student to develop the habit of consulting the technical press and professional journals in his field. The library should also support adequately the nontechnical portion of the curriculum.

(B) Report on Recommended Guidelines for Evaluation and Accreditation of Four-Year Programs of Engineering Technology

This 1966 report of the Committee for the Development of Guidelines for Evaluation and Ac-

[1] The anticipations of both the 1955 and 1962 ASEE reports with respect to the area of technical skills seem to have been fulfilled.

creditation of Four-Year Programs in Engineering Technology Education, known as the McCallick Report, followed the ECPD decision of 1965 to include four-year or baccalaureate Engineering Technology programs in its list of accredited curricula. This committee was appointed by the Chairman of the ECPD Committee on Engineering Technology to develop criteria to guide the accreditation process for baccalaureate engineering technology curricula. The following quotations are from this 1966 report.

Recent Developments

Three recent developments are important:[1]

First — programs with a vocational heritage and flavor have been modified and extended, in some cases to two years of post-secondary education leading to associate degrees. Some important distinctions of kind and quality have been blurred by the extension of these vocationally-related programs and their identification as engineering technology programs.

Second — the emergence from an industrial arts heritage of four-year degree programs most commonly designated industrial technology. Long standing bachelor's degree programs in industrial arts or industrial education are now being paralleled by degree programs in industrial technology to prepare graduates for industrial employment.

Third — enrollments in technical institutes (two year programs) have been at a virtual standstill for the last five years while enrollments in programs leading to baccalaureate degrees have soared.

Concepts Underlying the Recommended Criteria

The Committee feels that it should maintain meaningful distinctions between engineering and technology, between the purposes of the respective programs, and between the normal roles and career patterns of the graduates.

In this report technology concerns the achievement of some practical objectives through the application of proved "techniques", methods, and procedures.

Most engineering problems have no single or obvious best answer and hence require engineering judgment of the most appropriate balance between competing requirements. Technical problems are more likely to have unique and specific solutions. Most truly engineering problems have one or more important nontechnical constraints (legal, social, economic, aesthetic, etc.). Engineering is a profession in part because of the engineer's responsibility to society to take account of these nontechnical dimensions and thus protect and serve society's interests. The technologist or technician, as such, has no comparable professional obligation. Once the engineer has rendered a professional judgment on such relevant nontechnical dimensions of an overall engineering problem, and thereby stripped it to its technical core, if the remaining problem involves no novel technical features and requirements, the engineer may appropriately rely for the technical design upon a technologist.

We are anxious to avoid the development of any competition between engineering and technology education. They are natural supplements rather than competitors and it is our responsibility to make this eminently clear.

[1] These three developments as seen in 1966 are still continuing. They form the basis for considerable concern that distinctive criteria for four year engineering technology programs have not as yet been put into effect in accreditation.

Recommended Criteria

A. Program Designation. The committee recommends that the program be designated by the noun *technology*, not *engineering*. The adjective "engineering" in the compound term "engineering technology" would be approved. In every respect, the institution must make it eminently clear that the program is a technology program (not an engineering program) preparing technologists and technicians (not engineers).

B. Degree Designation. The committee expresses a strong preference for "Bachelor of Technology" as the name of the degree.

C. Entrance Requirements. The committee recommends that the entrance criteria now employed by ECPD for the accreditation of engineering technology programs be continued unchanged.

D. Program Arrangement. The committee approves either the integrated single four-year curriculum or the two-plus-two plan whereby the first two years lead to the associate degree.

E. Total Credits Required. The Committee recommends that the total credits required for graduation range between 120 and 144 semester hours exclusive of ROTC and physical education. The Committee prefers the low end of the range.

F. Subject Matter Distribution.[2] The committee recommends the following distribution:

1. Communication, humanities and social sciences	20%
2. Mathmatical and physical sciences	20%
3. Technical science	15%
4. Technical specialty	25%
5. Technical electives	10%
6. Free electives	10%

Definition of Technical Sciences. In these courses the technologist learns the theoretical characteristics and properties of devices and systems and the appropriate methods of analysis — mechanics, electric circuit theory, fluid mechanics, thermodynamics, etc.

Definition of Technical Specialty. (a) Technical Skills and Techniques include graphics, surveying, construction techniques, production methods, maintenance, etc. (b) Technical Design courses include practice-oriented standard design applied to work in the field — such as construction — in which the student acquires experience in carrying out established design procedures.

Technical Electives. These support the student's career interests, and may include not only additional mathematics, natural science and technical science, but also labor relations, cost accounting, contracts and specifications, etc.

(C) ASEE/ECPD Report on Terminology For Engineering Technology

In 1967 a joint committee of ECPD and ASEE made recommendations on terminology for engineering technology that have improved communications. The report covers terminology applicable to institutions, graduates and degrees. The following refers to institutional terminology:

[2] In 1970, the Board of Directors of ECPD approved "Interim Criteria for the Accreditation of Baccalaureate Degree Programs in Engineering Technology" which are slightly different from those shown here; the differences, however, are relatively minor.

> It is recommended that the term "Technical Institute" be used as the generic term to designate the institution or unit awarding the associate degree in engineering technology; and that the term "College of Technology" be used as the generic term to designate the institution or unit awarding the baccalaureate degree in engineering technology.

On the subject of designation of graduates the report states the following:

> It is recommended that the term "engineering technician" be applied to the graduates of the associate programs in technology and that the term "engineering technologist" be applied to the graduates of the baccalaureate program.

It was found that a considerable range of degree designations are used, including the following: Associate in Science, Associate in Applied Science, Associate in Engineering, Associate in Technology, and Associate in Engineering Technology; and also Bachelor of Science, Bachelor of Technology and Bachelor of Engineering Technology. For clear and unambiguous identification of graduates the following recommendations were made:

> It is recommended that the transcript and the diploma indicate clearly that the program is one in engineering technology.
>
> It is recommended that the degree designation include the term engineering technology.

It is believed that there is a continuing influence of this report which is gradually bringing greater consistency to the terminology of engineering technology education, thus clarifying both its relationship to and its separation from engineering education.

Section 4

Recent Trends in Engineering Education and Engineering Technology Education

Changes in Engineering Education

The education of the engineering technician and the engineering technologist bears an inadequately defined but important relationship to engineering education. Engineering education programs appear to be again undergoing a rapid evolution. After a period in which undergraduate engineering curricula were being extended to a point where only exceptional students finished in four years, and five-year undergraduate curricula were being tried in a few institutions, a reversed trend has developed. Baccalaureate engineering curricula that can realistically be completed in four years, of comparable length to curricula in liberal arts or science, now exist in significant numbers, a trend which seems likely to continue. This trend is not due to a belief that engineering education can be completed in a normal four-year curriculum. Instead, it seems related to a growing belief that an engineer who carries full professional responsibility should have a more extensive educational background than is commonly credited in professional circles to the baccalaureate degree.

Advanced Degrees in Engineering

Whether the advanced professional education of the engineer is conducted as study for the traditional master's degree or for an advanced professional degree, the result seems likely to be an extension beyond four years that will effectively increase the differentiation between the education of the professional engineer and the engineering technologist. Such a change may be expected to develop gradually; in fact, it has been in process for some time since approximately forty percent of new engineering employees in 1969-70 had advanced degrees.

Trends in Engineering Technician Education

The growth of technician education at the associate-degree level is a result of the establishment of large numbers of public junior or community colleges. Enrollments in long established technical institutes have not been growing significantly. The technical programs of the junior colleges are extremely variable both in their objectives and their quality. It has been observed that many represent an outgrowth from earlier concepts of vocational training. Some will continue within this type of environment while others, because of changing community needs, backgrounds of faculty, and other factors, have already changed in character. Two natural steps of evolution are identifiable: first, the introduction of a limited math-science requirement leading into specialized courses related to industrial processes; and second, strengthening of the math-science requirement for use in technical courses taught at least in part by engineers. At this stage the curriculum may qualify as an associate degree program in engineering technology, and perhaps receive ECPD accreditation. Junior colleges have not requested accreditation in significant numbers as yet (in 1970, the ECPD Annual Report listed fifteen community colleges with one or more accredited associate degree curricula in engineering technology).

Roots of Baccalaureate Technology Education

Baccalaureate technology curricula have roots in several areas of education. First, there have long been baccalaureate curricula in mechanized agriculture, building construction, printing, glass manufacture, furniture production and other industrially related areas. In some areas, such as textiles and petroleum, engineering accreditation for the program was sought; in others, it was not, probably because the arts were more important than the sciences in those fields. Another source of technology curricula has been the industrial arts programs of certain colleges of education where an evolution has taken place and "industrial technology" curricula have emerged. Because mathematics and science were not traditionally emphasized in curricula for industrial arts teacher preparation, the technological curricula stemming from this source have been initiated with about equal emphasis upon math-science-technical requirements and non-technical studies. It seems evident that the less encompassing math-science-technical content of curricula that have developed out of industrial arts education, commonly termed industrial technology, along with their emphasis upon management, account for rather rapid increases in their enrollments. A third source has been vertical extension to the baccalaureate level of the curricula of technical institutes which usually include a relatively large math-science-technical content.

Contemporary Developments in Technology Education

The most important recent trend in technological education is the interest of many universities in providing baccalaureate curricula in engineering

technology. In some cases, the technology curricula are offered within colleges of engineering while in others these programs are provided through colleges of technology or other administrative units. Under either of these organizational plans, the faculty of the technology unit is likely to be composed heavily of teachers with considerable industrial or other experience relevant to the curricular specialty. A major fraction of those who teach technical courses may be engineers. A factor that has disturbed engineering faculties is the rapid growth in student enrollment which has followed the inauguration of nearly all of the new baccalaureate technology programs while engineering enrollments have remained almost static. This condition may be attributed to the fact that only a small fraction of high school students show a strong interest in mathematics and science. Yet all are exposed to the marvels of an increasingly technological world. Thus an educational channel that provides professional or para-professional status through technological employment without the rigorous math-science requirement of engineering curricula appeals to many high school graduates.

An important contemporary educational experiment is noted in what are called "two-plus-two" baccalaureate technology programs, those designed to attract enrollment from students who have previously achieved an associate degree. The associate degree vocational-technical programs of many junior colleges are attractive to some students, but they still suffer in enrollment from their historical connection and, in some states, current association with "terminal" education. However, growing numbers of universities and colleges are accepting at least the above-average graduates from two-year technical programs into baccalaureate curricula in technology. Usually some academic time is lost by transfer, but if these transfers prove reasonably successful, the result on enrollments in junior college technical programs may be dramatic. The increased enrollments would then produce an enhanced flow of associate degree technicians into industry as well as a consistent flow of transfer students at the junior level into baccalaureate technology programs.

The Role of Corporate Schools

During the past five years, there has been a significant movement of major corporations into the field of post-high-school technical education. The Radio Corporation of America has operated a technical school since 1909, but it was not until 1965 that industrial firms entered technical education in appreciable numbers. A survey in 1970 revealed that about 65,000 students were enrolled in schools controlled by large manufacturing corporations; at least half of these students were studying technician courses of various lengths and sophistication with purposes ranging from service objectives to the baccalaureate level. Such corporate enterprise may grow to provide an important source of technological manpower and may have a significant impact on American technical education.

Employment of Technicians and Technologists

As yet the number of graduates from baccalaureate technology curricula is small compared to the number of engineering graduates, but the growth trend is clearly upward. The absorption into industry [1] of these graduates should not provide any problem at least for the next decade. Engineering technicians historically have been in short supply.

Data from the Bureau of Labor Statistics indicate that currently about one million technicians are employed (BLS, 1970; see Appendix B). Of these, about one half have no formal education beyond high school. The remainder have one or two years of post-high-school education, but only half of these seem to have received an education of two years closely related to their employment as technicians. It is likely that future utilization patterns for technical manpower will call for enhanced preparation of the individuals entering technical employment. By 1980, employment priorities may justify some 50 percent of new entrants to technician jobs to be educated to the associate-degree level and another 25 percent to have baccalaureate technology degrees. If four-year engineering and industrial technology education should grow in volume to equal the production of engineers, it would then require, allowing for usual losses, nearly a ten-year output from such baccalaureate technological curricula to replace with such graduates one-fourth of the one million technicians now employed by industry and government. By that time the needs of industry for technological personnel would doubtless have grown commensurately.

Industrialists explain that they employ for technical jobs the best qualified persons available and provide as much training as is essential to achieve the necessary productivity. Baccalaureate technologists are needed, but in their absence the best qualified technicians will be upgraded to achieve an acceptable result. The extent of the need for baccalaureate technologists will be largely invisible until such graduates become available in significant numbers for employment. The increased cost of using minimally qualified employees is equally indeterminate.

Societal Aspects of Technological Education

Since the baccalaureate engineering technologist will doubtless in due time be recognized as a member of a profession, he must develop the so-

[1] Where the term *industry* is used in this report, it is intended to have a broad connotation. As used herein, *industry* includes not only machine and electronic production industry, but the construction industry, the chemical industry, textiles, food, transportation, housing, pollution control, urban renewal and every phase of life and society influenced by modern technology. Reference to the employment of engineers, technicians and technologists "in industry" is intended to include those employed in government at all levels and in private consulting firms as well as in firms oriented toward manufacturing and commerce.

cietal responsibility expected of every professional. Immediately he may function under the codes of ethics of engineering societies but eventually he will undoubtedly develop a code of ethics more directly applicable to his particular activities and responsibilities.

The engineering technologist will soon be involved in making his particular type of contribution to the solution of many current problems of modern society. There are contributions that can readily be made to solving many widely discussed problems without new research. We know much that we apply inadequately to urban overcrowding, crime reduction, air pollution, transportation, public health, natural resources, water conservation, lake and river contamination, wild life preservation, noise abatement, etc. The opportunity for technologists to work in such fields seems likely to increase.

In their present stage of development, curricula in engineering technology usually contain less mathematics, science and technical subjects than engineering curricula of four years duration. Engineering technology under liberal direction may therefore offer to some students a fairly extensive opportunity to expand the usual social-humanistic courses into a study of considerable depth in some non-science area such as economics, sociology, political science, law or humanities. Such an interdisciplinary interest may be expected to lead students toward an opportunity to contribute to future technological solutions of societal problems. Other possibilities of non-scientific emphasis are, of course, management and international trade or foreign relations. Technology students who show an interest in interdisciplinary studies should be encouraged.

Section 5

Goals, Objectives, and Broad Features of Engineering Technology Education

Engineering technology education by definition must be more intimately related to engineering education than are other technological educational programs that also build upon mathematics and the physical sciences. This close relationship is essential because engineering technology education prepares engineering technicians and technologists to serve with engineers as part of the total technological enterprise that extends from planning to production and continuing service. The engineering technician and technologist must, therefore, understand the language of engineering — written, symbolic and graphic, must be able to interpret in material terms the results of engineering analysis or design, and must work effectively as a member of the total technological team. The engineering technologist often carries some responsibility for the achievement of the physical result that derives from creative engineering planning and design. This does not mean that the engineer is uninterested or uninvolved in the practical output of his creative work, but he no longer needs to oversee all the details of installation, operation, production, and maintenance of his engineering projects.

The Overall Educational Objective

Engineering technology education is designed to educate two-year, associate-degree engineering technicians and four-year, bachelor-degree engineering technologists either to assist engineers or to provide independently the support for engineering activities of a formulated or practical nature for which contingencies requiring decisions based upon full knowledge of the engineering design are uncommon. The essential content of engineering technology curricula — independent of length — must therefore be mathematics, basic science, technical science, and a technical specialty to a level consistent with the primary objective as stated, along with technical skills related to a particular area of engineering practice. As a corollary, technological curricula that train individuals to work in the fields of science, business, marketing, data processing, health or agriculture are usually not properly classified as *engineering* technology although overlapping objectives may exist.

In order to achieve the objectives of the ASEE Engineering Technology Study it is necessary to determine the primary characteristic or special quality that distinguishes the engineering technologist from the engineer on the one hand and from other kinds of technologists or technicians on the other.

The Central Objective of Engineering Education

In 1950, Dean S. C. Hollister made a useful contribution to the definition of an engineering curriculum by emphasizing as the controlling objective the design of machines, structures or processes (Hollister, 1950). Today one would add the design of "systems" including social and human elements. However, the word "design" is not free from semantic confusion. It is widely used in a different context in associate degree programs of "drafting and design". Hence, it is necessary to distinguish between design based upon high level mathematics and science, involving analysis and synthesis, characteristic of the work of engineers, and "established" design, characteristic of the work of technicians or technologists, which follows codified procedures or is based upon a less extensive math-science background and which considers primarily the elements of a system rather than the system as a whole.

In 1950, greater attention naturally was given to defining the border area between science and engineering education than between engineering and technology education because the latter seldom exceeded two years and was often only one year in length. Now, engineering technology programs often extend to four years and lead to the award of baccalaureate degrees. However, it is obvious that these baccalaureate programs would not exist separately from engineering curricula if their goals and requirements were practically the same. Therefore, it is an important objective to search out and state clearly the essential differences between engineering and engineering technology education particularly when they are of the same duration in academic years.

The Math-Science Background for Engineering Technology Education

The primary objective of any degree program in engineering technology can be deduced from the content of the curriculum itself. An important factor for consideration is the college-level mathematics requirement. Admission to a technology program is commonly based upon one year less and in some areas two years less of high school mathematics than is admission to an engineering program. Also, the high school science requirement for admission to engineering technology typically will be less than that required for admission to a school of engineering. In fact, there may be no science requirement for admission. It follows that a technological curriculum at the college level may be expected to include a less rigorous math-science

sequence than an engineering curriculum. Its math-science level establishes for a technology program the instructor's approach to a group of courses designated in this report as "technical science". Such courses are taught with the emphasis upon applications or standardized solutions of common problems rather than the engineering approach which de-emphasizes formulas and channelized procedures.

Other Curricular Areas in Engineering Technology

When standardized calculation techniques are carried forward into design as a part of technology education, it is evident that the concept of overall engineering design based upon analysis and synthesis, which at times requires calculus and other advanced mathematics, cannot be given major attention. Hence, the design instruction of the engineering technologist involves carrying out established procedures of design. Thus he develops a sufficient understanding of engineering design so that he may carry engineering projects forward into practical production, operation, and maintenance. The major technical specialty and related technical studies are the essential core of any engineering technology curriculum.

A goal of immediate usefulness of graduates to their employers is considered important in designing two-year engineering technology curricula and is also emphasized in four-year curricula. To this end, a study of the use of equipment is a common characteristic of engineering technology programs. Also, communication skills require attention in all engineering technology curricula, and general or liberal education is an important objective at the baccalaureate level.

Supervision and Management

The study of supervision or management is seldom a central characteristic of engineering technology education. The engineering technologist often directs others, but the same is true of engineers and the members of many callings. Attention to management even in four-year engineering technology curricula is limited to a small fraction of the curriculum (some five percent) by need for advanced courses in the technical specialty and required breadth of technical studies. Management is sometimes included as a small part of humanistic-social study, but it must not be permitted to displace required liberal studies. It follows that the study of management is a *desideratum* rather than an indispensable part of an engineering technology curriculum. This is in contrast to industrial technology programs for which a primary objective is training for supervision or management achieved by trade-off with the technical depth of the curriculum.

Summary: The Central Objective of Engineering Technology Education

This analysis has established the central purpose of engineering technology education to be support for the practical side of engineering achievement with emphasis upon the end product rather than the conceptual process. There are many overlapping areas, but, in broad outline, the engineering technologist may be said to help achieve what the engineer conceives. The technologist is usually a producer, the engineer is more often a planner. The technologist is valued as an expediter, the engineer is sought as an expert. The technologist should be a master of detail, the engineer of the total system. Hence we may characterize engineering technology education as follows:

> In contrast to engineering education where capacity to design is the central objective, engineering technology education develops capacity to achieve a practical result based upon an engineering concept or design either through direct assistance to an engineer, in supervision of technically productive personnel, or in other ways.

Where the work of the technologist and the engineer are similar in kind they may be expected to differ in level because of the differences in mathematics, science and engineering science in their educational backgrounds. The development of methods or new applications is the mark of the engineer. Effective use of established methods is the mark of the technologist. The engineer's interest and attention must carry through to the final product of his creativity and its effective use. However, it is no longer necessary that he perform all of the technical functions from conception to completion of a new product or process and then exercise the continuing technical controls. The engineer's most important work is usually concentrated in the early stages of a project. The engineering technologist may perform similar activities to those of the engineer but at a different and usually later stage in the progression from concept to product except when he serves directly as an aid to the engineer.

Section 6

Characteristics of Associate Degree Curricula in Engineering Technology

Institutions Offering Associate Degree Engineering Technology Programs

There exists no authoritative list of institutions which offer associate degree curricula in engineering technology. A number of recent publications, however, provide data from which reasonable estimates may be made. In 1969, the Engineering Manpower Commission conducted a survey to determine the number of associate degrees awarded in technology; the report of this survey stated that 394 institutions had made associate degree awards during the 1968-69 academic year (Alden, "Technology Degrees", 1970). Earlier, the National Center for Educational Statistics of the U.S. Office of Education had furnished data in a different format, suggesting that during the 1967-68 academic year approximately 450 institutions made "formal awards" (these awards included both certificates and associate degrees) to students completing programs "at the technician or semiprofessional level" (NCES, "Associate Degrees . . ." 1969). And more recently, the Engineering Manpower Commission has published data on the Fall 1969 enrollments in institutions offering technician and/or pre-engineering programs (EMC, "Enrollments," 1970) which indicate that about 550 institutions are engaged in this activity. Combining the two lists of institutions reporting to the Engineering Manpower Commission with the list reporting to the National Center for Educational Statistics is believed to produce a list of acceptable coverage. The combined list contains 563 institutions. These institutions offer approximately 1600 individual curricula.

Institutional Classification

The institutions offering educational programs in engineering technology are of various types. They belong primarily to one of the following classifications:

1. *Monotechnical Institutes.* Single purpose institutions having engineering technology education as their sole institutional objective.

2. *Polytechnical Institutes.* Institutions with a variety of objectives related to technical and occupational fields, including programs related to business, health, or public service as well as to engineering.

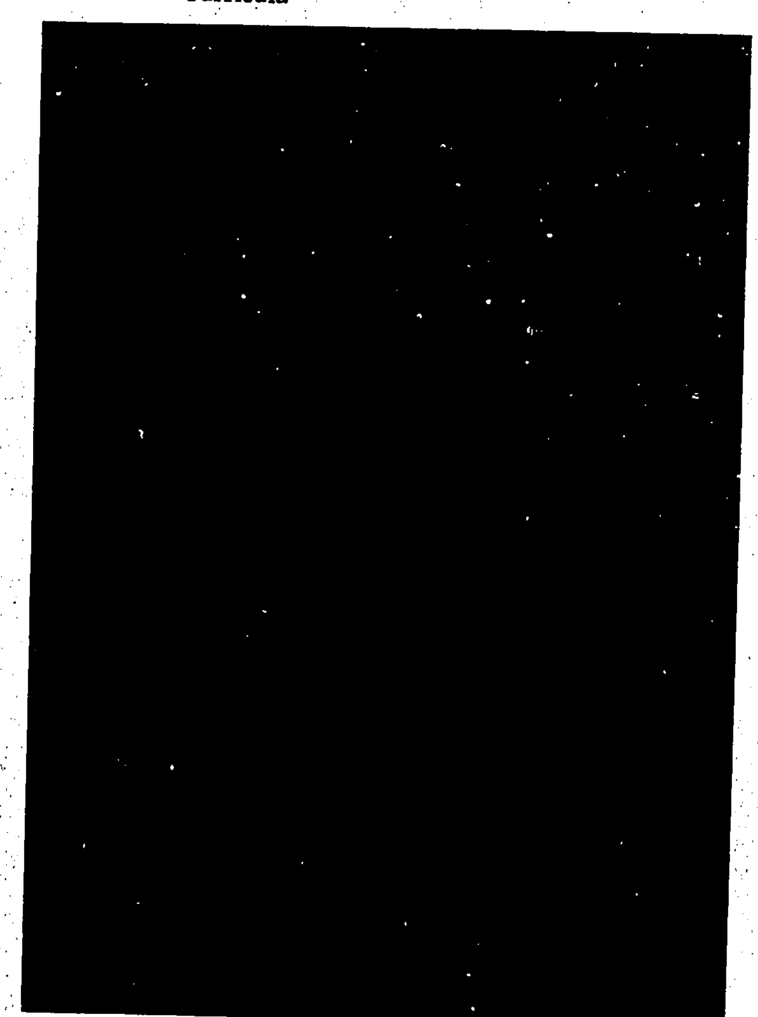
3. *Comprehensive Community Colleges.* Community and/or junior colleges which include in their offerings various occupational-technical programs as well as "university parallel" or "transfer" programs.

4. *Universities.* Senior institutions (universities, colleges, or other, regardless of the actual names of the institutions) which include associate degree programs in engineering technology as part of their offerings, either on the main campus or at a branch campus.

The largest proportion of enrollments is found in the comprehensive community colleges, although curricula having accreditation by the Engineers' Council for Professional Development are found to the greater proportion in monotechnical and polytechnical institutes.

Table 2 summarizes some of the general characteristics of the approximately 560 institutions which offer associate degree engineering technology curricula.

Table 2. General Characteristics of Institutions which Offer Associate Degree Engineering Technology Curricula



Associate Degree Engineering Technology Curricula

Associate degree engineering technology curricula, although they differ from one another in certain respects, have many characteristics in common. For example, a recent study of a selected

national sample of 120 such curricula[1] revealed the existence of a basic *structural profile*, that is, a common pattern of curriculum structure based on the number of semester hour credits required in various curricular areas. The 120 curricula studied were identified as programs of quality which were perceived to have potential influence on the future of engineering technology education. *Subsequent data tables and figures in this chapter are all based on this sample of curricula.*

Definition of Curricular Areas

The primary purpose of the study just mentioned was to discover the extent to which various subject matter areas were treated in associate degree engineering technology curricula. The definitions of curricular areas used for the purposes of the study are as follows:

> Technical specialty. Technological subject matter content in an engineering technology curriculum in which a student concentrates study; the "major" of a curriculum. For example, technical specialty subject matter in an electrical technology curriculum usually will include college courses entitled "electrical machinery", "transmission networks", "microwaves", and the like.
>
> Related technical studies. Technological subject matter content in an engineering technology curriculum related to an area of technology or to the development of skills to support a technology, but not directly related to the area of specialization; courses which support the major. Basic electronic circuits taught to mechanical engineering technology students is one example; introductory drafting is another.
>
> Technical sciences. Subject matter content in an engineering technology curriculum having its roots in mathematics and basic science but carrying knowledge further toward applicability; courses designed to supply the core of technological knowledge the student needs in his chosen profession. While more limited than the "engineering science" of a professional engineering curriculum, the same areas are included. For example, the technical sciences include such subjects as "applied mechanics", "strength of materials", "fluid flow", and the like.
>
> Physical sciences. Chemistry, physics and integrated courses in chemistry and physics.
>
> Mathematics. Subject matter content beyond the level of "intermediate algebra"; "college algebra" and other mathematics subjects including trigonometry and calculus which have college algebra as a co- or prerequisite.
>
> Communications. Subject matter content related to grammar, rhetoric, speech, technical writing, and other phases of language except literature.
>
> Humanities/Social Studies. Subject matter content related to literature, the arts, philosophy, history, sociology, political science, and the like.
>
> Other studies. Subject matter content in a curriculum not classifiable under one of the preceding categories; these include R.O.T.C., physical education, life science, foreign language, and "free electives" not identifiable by category.

Findings from a Study of 120 Associate Degree Engineering Technology Curricula

Table 3 summarizes the structural characteristics found for the sample of associate degree engineering technology curricula in terms of the number of semester credits typically required in each of the curricular areas just defined. The table lists the range of requirements found to exist in the 120 curricula studied, the mean (arithmetic average) of these requirements, and the mode (highest frequency) of the requirements; the mean has been adjusted to the nearest half-credit for convenience in reporting.

Table 3. Structural Characteristics Found in a Sample of 120 Associate Degree Curricula in Engineering Technology[a]

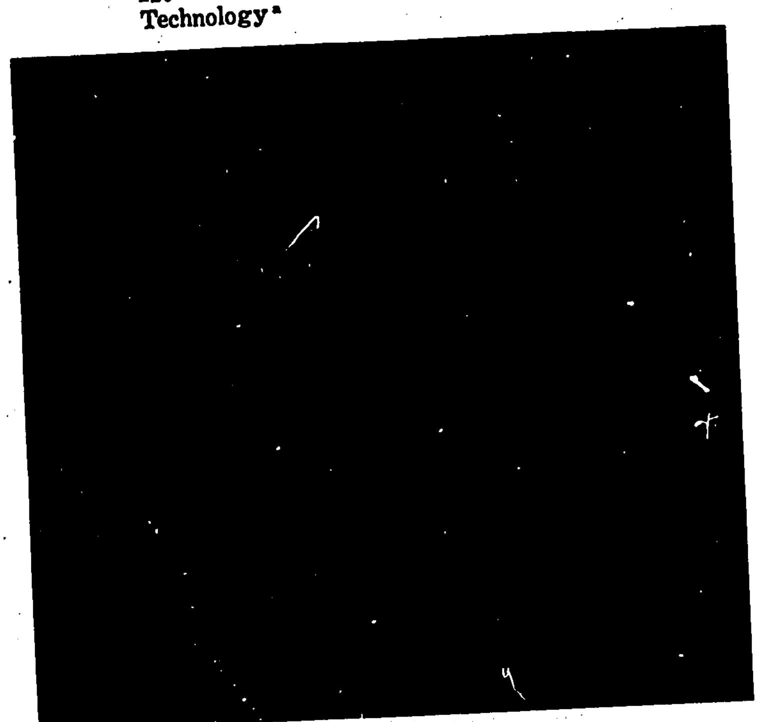
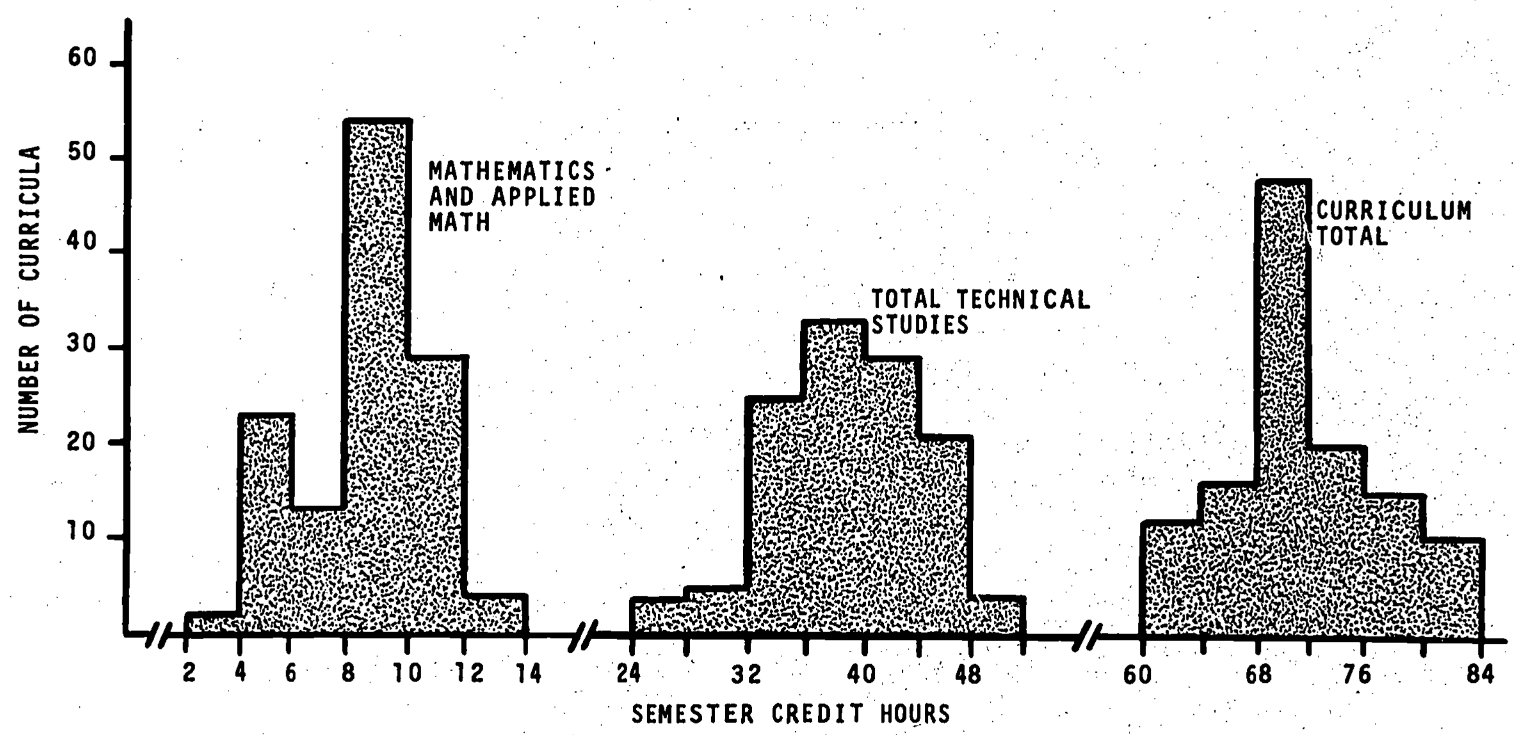


Figure 1 gives some insights into the kinds of structural variations and central tendencies which existed in the group of 120 curricula on which Table 3 was based. Figure 2 displays graphically the structural profile of these engineering technology curricula in terms of modal credit hour requirements. The mode was used on this diagram because it is the more useful statistic to describe usual practice and has the advantage of easy interpretation in terms of the credit values normally assigned to college courses. Three major content areas in the curriculum can be identified. These are the *technical courses* (including technical specialties, related technical studies and technical sciences), *basic science courses* (including mathematics and the physical sciences), and *non-technical courses* (including communications, humanities, social studies, and other such content). Figure 3 shows the proportions of the curriculum

[1] This study was conducted during the spring of 1970 by the staff of ASEE's Engineering Technology Education Study to provide background information for the Advisory Committee. The 120 curricula studied, although not necessarily selected to satisfy statistical criteria for randomness or representativeness, were deemed appropriate for the purposes of the investigation. They included 18 identifiable technical disciplines, were found in a variety of institutional settings, and were reasonably distributed by geographic region of the country; 71 of the curricula had been accredited by ECPD. For a more detailed description of the sample and a complete report of the study, see Jesse J. Defore, *Technician Monographs: A Collection of Papers and Research Studies Related to Associate Degree Programs in Engineering Technology* (Washington, D.C.: ASEE, 1971), Chapter 2.

Figure 1. Distribution of Semester Credit Requirements in Selected Curricular Areas in 120 Associate Degree Engineering Technology Curricula.

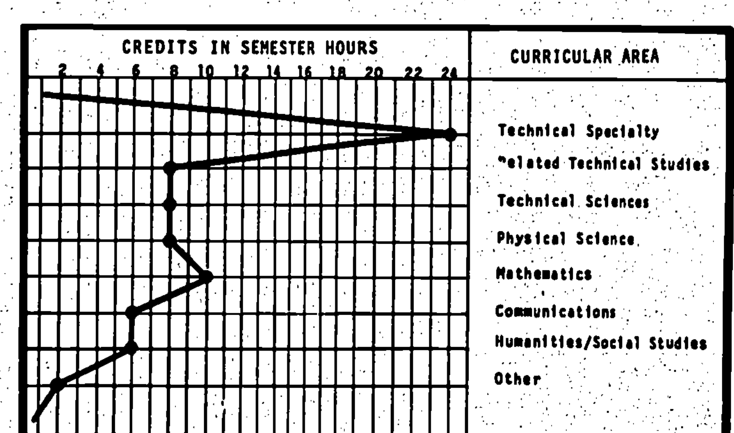


typically devoted to each of these major areas and to their components. Associate degree engineering technology programs, even though they may vary somewhat among themselves in their emphasis within the three major areas, are highly consistent in their pattern of distribution of required credits into these major curriculum areas. It is noted that the total nontechnical content is restricted to 20 percent, leaving 80 percent for the math-science-technical content of the curriculum.

Consistency in Curricula Examined

The curriculum structures of associate degree engineering technology programs are often quite similar in detail as well as in the general distribution of credits into the technical, basic science and non-technical areas. Examination of individual cur-

Figure 2. Modal Structural Profile Found for a Sample of 120 Associate Degree Engineering Technology Curricula.



Total Credits in typical curriculum = 72 semester hours; Total Technical Credits (Technical Specialty, Related Technical Studies, Technical Sciences) = 40 semester hours; Total Math-Science-Technical Content = 58 semester hours or 80 percent of curriculum.

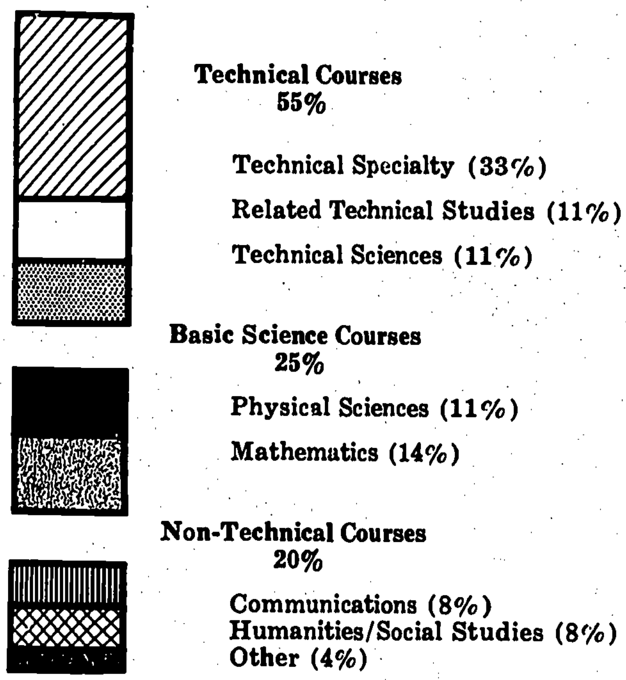
riculum outlines as published in institutional catalogs or bulletins reveals that many associate degree engineering technology programs have profiles which trace major sections of the modal profile shown in Figure 2. One possible explanation of inter-program consistency can be offered. ASEE's *Characteristics of Excellence* (the McGraw Report of 1962) suggested certain guidelines for the structure of engineering technology curricula. An illustrative curriculum was presented, showing a possible distribution of course credits in certain curricular areas (see page 7, herein). That suggested distribution is shown in Table 4, together with corresponding data for the curricular areas of the modal engineering technology program discussed above. Examination reveals a high degree of correspondence between items in the table; the 1962 McGraw Report has evidently had an appreciable directive influence on the evolution of associate degree engineering technology education programs.

Curricular Differences in Programs

Individual associate degree engineering technology programs sometimes have curriculum structures which deviate from the modal pattern. In the sample of curricula studied, certain factors seem related to variances in structural profiles.

One factor which can be associated with such variance is the *institutional setting* — monotechnical institute, polytechnical institute, comprehensive community college, or university — in which a curriculum is offered. The curricula found in monotechnical institutes, polytechnical institutes and universities have quite comparable structures; however, curricula in comprehensive community colleges generally differ from the others in certain ways. First, community college programs tend to be shorter, requiring fewer total credits for the

Figure 3. Distribution by Major Content Area of Required Credits in a Sample of 120 Associate Degree Engineering Technology Curricula.



associate degree. Secondly, community college curricula generally list fewer requirements in the math-science, the technical, and the humanistic-social areas. And finally, community college curricula usually permit more credits to be earned as free electives or "other" content. When these divergences become severe, the curriculum may not justify designation as engineering technology.

The *technical discipline* on which the curriculum places emphasis is another variable influencing curriculum structure of associate degree engineering technology curricula. For example, electrical technology curricula are likely to require a greater proportion of their credits in mathematics and the technical specialty than are mechanical technology curricula; the latter, on the other hand, generally have substantially higher requirements in the "related technical studies" area than do electrical technology curricula, even if offered at the same

Table 4. Distribution of Credits in McGraw's "Illustration" and in the Modal Associate Degree Engineering Technology Curriculum of 1970

Curricular Area	Semester Credit Hours			
	Suggested by McGraw, 1962		Modal Program, 1970	
Total Technical Studies	39		40	
Physical Sciences	6	57	8	58
Mathematics	12		10	
Communications	6		6	
Humanities/Social Studies	6	15	6	14
Other	3		2	
Curriculum Total	72 Sem. Hrs.		72 Sem. Hrs.	

institution. Variations of this nature are not unexpected.

Curriculum Trends for Associate Degree Curricula

Several curriculum trends in associate degree engineering technology education programs were noted. These trends may be related to an increasing sophistication and complexity of the technological environment and they may have important implications for future developments in engineering technology education. First, subjects with titles such as "introduction to computers", "computer programming", "applications of data processing", and the like were found in many of the published curriculum guides for engineering technology programs. Second, the published curriculum guides tended to give separate identification for coursework belonging to the "technical sciences" area. This classification or area has been used throughout this document, for the trend has seemed clearly established; the McGraw Report and other earlier literature, however, did not use this curricular area as a separate category. And third, there was observed a reduced emphasis on skill courses. Published curriculum guides showed such subjects as "machine shop", "welding", "wiring", and the like to a lesser extent than earlier had been the case; a course in drafting, however, remained a part of most curricula.

Section 7

Desirable Characteristics of Associate Degree Engineering Technology Curricula

An associate degree engineering technology curriculum is a special purpose, collegiate program of studies, normally of two academic years duration, which prepares engineering technicians to assist engineers or to provide independently the support for engineering activities. Such a curriculum desirably provides education of such quality, scope and depth that its graduates will have acquired the knowledge, skills and competencies to enable them to contribute substantively and immediately to their employment situation. In addition, the associate degree engineering technology curriculum desirably provides a base from which individuals can adapt and change as their work roles change within an evolving technological environment.

Minimum Criteria for Two-Year Engineering Technology Curricula

The Advisory Committee has concluded that the "Curriculum Summary" of the 1962 McGraw Report (see page 7, herein) remains valid in terms of the minimum requirement of 60 semester hours. At the present time, many curricular variations exceeding this minimum exist with the objective either of increased technical specialization or increased breadth; for example, the modal curriculum of 1970, reported in Section 6, included 72 semester hour credits. Nevertheless, the Advisory Committee believes that a curriculum of quality can be planned that will not exceed two academic years; such a program might be limited in some institutions to 60 semester hour credits. Accordingly, the suggestions in this report for time allocations within an engineering technology program will be expressed in terms of academic years rather than credit hours.

Curriculum Components for an Engineering Technology Program

An associate degree engineering technology curriculum is regarded as having four major curricular subdivisions, as follows (for detailed definitions, see Section 6):

(a) *Technical Studies*, which include the major technical specialties, related technical studies, and the technical sciences.
(b) *Basic Science Studies*, which include mathematics, applied mathematics, and the physical sciences.
(c) *Non-technical Studies*, which include communications, humanities, social sciences, and other life-oriented subject matter.
(d) *Institutional Electives*, which may include additional technical, basic science, or non-technical studies, R.O.T.C., physical education, or other content considered necessary to maintain the integrity or achieve the special purposes of an institution of higher education.

The inclusion of "technical science" in the components of the engineering technology curriculum is an addition to the concepts of the McGraw Report. Study of the technical sciences will, it is believed, substantially enhance not only the immediate competency but also the long-term technical viability of an engineering technician, rendering him less vulnerable to early obsolescence. About one-third year devoted to the technical sciences is suggested as a factor that adds strength to an engineering technology curriculum.

A Suggested Curriculum Guide

The Advisory Committee suggests that an associate degree engineering technology curriculum of quality can consist of the components and time allocations as shown in Table 5. It is emphasized that the recommendations in the table are for a two-year, associate degree program in *engineering technology;* curricula which may be technically oriented but which have educational objectives outside the domain of engineering technology education may be expected to differ in length and pattern from the suggestion shown.

Quality and Level of Associate Degree Programs

There are many factors other than the curriculum that influence the effectiveness or quality of an engineering technology program for the associate degree. It is well to emphasize that level and quality are not the same. Level refers to the program's goal, which is clearly different for two-year and four-year programs, while quality is a measure of goal achievement. The goals for the associate degree must be related to a reasonable two-year accomplishment of typical entering students and is therefore related to standards of admission. Remedial work may be provided for a minority of the entering students, and if prerequisites are fully maintained, the quality of the program should not suffer. Such remedial work would extend a student's program beyond two academic years.

Faculty Qualifications

Of equal importance to the possible achievement level of the students is the achievement level of the

Table 5. A Suggested Curriculum Guide for Associate Degree Curricula in Engineering Technology

Curricular Area	Approximate Time Allocation in Academic Years
Technical Studies Technical Specialty (courses in the technology major) Related Technical Studies (courses which support the technology major) Technical Sciences (topics from the area of the engineering sciences	**About 1 year**
Basic Science Studies Mathematics (algebra, trigonometry, calculus, applied mathematics) Physical Sciences (physics, chemistry)	**About ½ year**
Non-technical Studies Communications (English composition, speech, report writing) Humanistic-Social Studies (literature, art, history, economics, etc.)	**About ⅓ year**
Institutional Electives Subject matter to satisfy special institutional purposes	**To total 2 years**

faculty. Dedication to teaching is an essential characteristic, but for a specialized field of engineering technology education, both the educational level of the faculty and their industrial or other related experience are additionally important. Based upon the concept that the teacher must be educated to a higher level than the subjects he teaches, presently available teachers for the technical sciences and other applied sciences, technical specialties and related technical courses must be largely engineers or engineering technologists with enhanced math-science backgrounds. It is far more important that the faculty have a considerable background of practical experience currently related to the field being taught than that it provide a high percentage of advanced degrees for catalog display. Of course, the quality of instruction is influenced by the time the faculty has available to instruct, to discuss and to counsel with students. Except for reduction or absence of a research demand upon the faculty, there is no justification for higher teaching loads in engineering technology than elsewhere in the institution.

Space and Facilities

It is not possible to give quantitative measures short of accreditation criteria that determine the quality of such factors as space, laboratory equipment, library holdings, computer time available to faculty and students, or even dollars spent per student. It is sometimes possible to build curriculum emphasis to reduce the influence of one or two physical inadequacies. However, a realization that both level and quality of an engineering technology program are related to physical factors will put these factors in proper perspective and hopefully lead to their improvement.

Conclusion

It is widely accepted that associate-degree engineering technicians remain in strong demand by employers. The technical institutes have provided a useful service by producing relatively high quality two-year graduates in engineering technology, but not in sufficient numbers to meet the industrial need. Much larger numbers of technicians are needed. The community colleges are the most significant sources of future technician manpower, but there is no assurance as yet that a significant percentage will accept the definitions of engineering technicians as presented in this report. Some time may have to elapse until the concept of accreditation for associate degree curricula in engineering technology is accepted by a large number of community junior colleges or until it is clear that even without accreditation they meet adequate standards of quality.

Section 8

Characteristics that Differentiate Between Baccalaureate Education in Engineering, Engineering Technology, and Industrial Technology

The first need is to define with clarity the field of baccalaureate engineering technology education. The key word involved is "engineering", an adjective used to distinguish the engineering technologist not only from such specialized professional groups as medical technologists but also to protect him from loss of identity in the broad field of industrial applications of technology. Because the distinguishing adjective is "engineering", it is necessary to affirm the most significant activities of the engineering profession to which the engineering technologist by name and by definition is closely related.

Engineering: A Creative Profession

Engineering has always been applauded as a creative profession. Ancient temples, bridges, aqueducts, medieval churches, and early skyscrapers represent a continuing sequence of creative accomplishments paralleled or followed by mechanical, electrical, chemical, aeronautical, nuclear and space achievements of fantastic brilliance. These are stars in the engineer's crown and no one doubts that there are many more to come. They also add luster to the technicians who contributed to each success. In an earlier age, creative technical achievements depended upon the genius or ingenuity of a single mind, a combination scientist-engineer-technician who was often master craftsman as well. Today, technological teams ranging from three or four individuals to hundreds may coordinate their efforts and pool their ideas to achieve a planned goal. The invention and production of new technical accomplishments are the responsibility of engineers. Supersonic aircraft, nuclear power plants and space exploration are examples. Scientists will contribute concepts, technologists conduct pilot experiments, technicians control quality, and craftsmen perform essential workmanship; but the creative application usually generates within the minds of engineers who bring together scientific knowledge and practical art to answer a need or produce a new product. The planning and organizational capabilities of engineers then contribute to the economical multiple output of such products for broad consumption, an equivalent engineering achievement.

The Scope of Engineering Curricula

The purpose of accreditation of engineering curricula should be to assure an education that will produce engineers who can create or who can plan, organize and manage highly sophisticated technical enterprises. Such training may reach an excessive depth for some who enter more standardized activities, but all who are educated as engineers should have the potential of contributing to society at the upper technological level which herein is termed creative engineering. It is necessary, therefore, that accredited engineering curricula include science and mathematics of considerable sophistication, at least through differential equations, and engineering science — in breadth to cover nearly all its areas and in depth for the area directly related to the curriculum major. In addition, humanistic and social studies are specified, not only as part of a liberal education, but also that the engineer may communicate and work effectively with others and recognize the impact on society of his work. These objectives carried out in full measure would fill a four-year program of study allowing for a few elective courses of special interest to the individual. However, to develop his potential of creative accomplishment, the engineer needs appreciable study of synthesis or design including systems analysis and exposure to the art of engineering; or for some the opportunity to penetrate deeply into a limited area which may initiate a career in research or development.

The subdivisions of the engineering curriculum as discussed above are inherent whether the time span is four or five or more years. These characteristics, therefore, define an engineering curriculum and may be used to differentiate it from a baccalaureate program in either engineering technology or industrial technology, or more readily from an engineering technician program which is usually of about two years in length.

The Scope of Baccalaureate Engineering Technology Curricula

If a baccalaureate curriculum of engineering technology is to produce graduates who can work closely with engineers, and after adequate experience accept responsibility for production of engineering work, there must be considerable overlap between each engineering technology curriculum and the related engineering curriculum. The engineering technology mathematics requirement need not be as advanced as engineering mathematics but it must provide an adequate base for a realistic study of physics and chemistry. This will require a study of the elements of differential and integral calculus but not of differential equations

except for a field such as electronics. Even so, the courses in mathematics in the baccalaureate engineering technology curriculum will normally avoid some of the mathematical rigor considered necessary for engineers. In turn, this will influence the content of the engineering technology courses in physics and in technical science even though the titles correspond closely with comparable courses for engineers. It seems unlikely that the four-year engineering technology curriculum can provide time for more than a very limited approach to engineering analysis and design. The remainder of the curriculum will be needed to provide the engineering technologist with at least as broad a liberal education as is extended to engineering students, sometimes including the elements of supervision, and with a reasonably extensive coverage of the art of the field including production methods and equipment.

The Scope and Objectives of Industrial Technology Curricula

One interface of engineering technology education is with educational programs of industrial technology. As stated previously, industrial technology programs evolved within departments of industrial arts education where some continue, but others have independent existence in any one of several colleges. Since the ASEE Study was not planned to survey curricula other than engineering technology, it has been necessary to rely upon published material in order to delineate the boundary area between engineering technology and industrial technology. For this purpose, a current and most useful study of industrial technology is the California State Colleges Report of 1970. An authorized abstract of this report, in considerable detail, was reproduced in the *Preliminary* and *Interim Reports*, from which a few excerpts are given herein as Appendix A. The abstract also provided considerable information applicable to engineering technology, including a useful industrial survey.

Definitions. It is useful to compare definitions of engineering technology and industrial technology. For engineering technology the accepted ECPD definition is as follows:

> Engineering technology is that part of the technological field which requires the application of scientific and engineering knowledge and methods combined with technical skills in support of engineering activities; it lies in the occupational spectrum between the craftsman and the engineer at the end of the spectrum closest to the engineer.

A key phrase for engineering technology is "in support of engineering activities".

Several interrelated definitions of industrial technology are quoted in the excerpts from the California State Colleges Report in Appendix A. For example:

> The graduate, through having knowledge of basic industrial skills, is oriented towards assisting and directing the development program, the flow of production, the distribution of the product, and other facets of general management. The technologist supervises operations involved in the development of a consumer product, or its movement to the distribution point, and even making it acceptable and popular on the open market. Some curricula offer variations in the business portion, permitting a sales emphasis, for example.

According to the National Association of Industrial Technology:

> The curriculum, even though built on technical education, has a balanced program of studies drawn from a variety of disciplines relating to industry. Included are a sound knowledge and understanding of materials and manufacturing processes, principles of distribution, and concepts of industrial management and human relations; experience in communication skills, humanities, and social sciences; and a proficiency level in the physical sciences, mathematics, design, and technical skills to permit the graduate to capably cope with technical, managerial and production problems.

The Principal Thrust of Industrial Technology Education

All educational programs are designed to achieve certain goals or objectives. Educational programs considered occupational — including professional — define one of their principal goals in terms of some area of employment, or it may be more narrowly stated in terms of a particular job. The goals statement is an important characteristic that differentiates educational programs.

The key phrases for industrial technology education, according to the California State Colleges Report, are "occupying the mid-ground between engineering and business administration", and "emphasizing the applied aspects of industrial processes and personnel leadership". These objectives are sufficiently removed from "in support of engineering activities" to make necessary different curricular emphases in industrial technology from those of engineering technology. Both types of curricula vary over a wide range so that each is best described in terms of a "median" or "modal" curriculum. Also, the emphasis upon "breadth" in industrial technology, which contrasts with "specialization" in engineering technology, can best be described in terms of broad curricular groupings, such as math-science-technical content *versus* non-technical content including management.

Charts that Present the Interrelationships of ET and IT Education

The logic of the analyses provided by the California State Colleges Study of Industrial Technology and the relative consistency of the responses to its industry questionnaire (see Appendix A) have led to ASEE's use of the CSC study as indicative of the development, status, and industrial acceptance at this time of industrial technology education. The CSC Study and its industrial survey fortunately also include sufficient attention to engineering technology for one to draw conclusions as to the relative position gradually being

assigned by educators and employers to IT *versus* ET education.

Figure 4 which accompanies this section has been prepared by the ASEE staff to illustrate graphically the interfacing, as suggested by the CSC Study, of industrial technology education and engineering technology education, and their external interfaces with engineering education and business administration. Also in Figure 4, a corollary diagram of employment depicts the external interfacing of ET and IT with engineering practice and with production. The counterflow arrows on the education diagram illustrate "increasing management training and business studies" with movement toward the right and increasing "math-science content" with movement toward the left. Similar counterflow arrows on the employment diagram point out the "increasing use of mechanical and management skills" with movement toward the right and "increasing conceptual activity and use of theory" with movement to the left.

Figure 4. Interfacing of Engineering Technology with Engineering and with Industrial Technology.

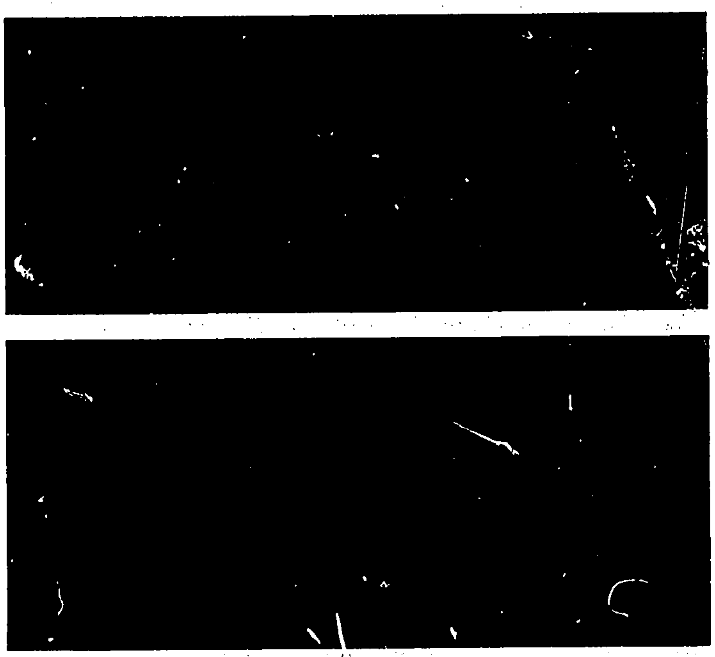


Figure 5. Major Interfacial Relationships in Technology Education and Employment.[a]

[a]Note: This diagram is to be read from left to right. The vertical positioning of various blocks merely illustrate interfaces. The entire diagram is properly viewed as being in the horizontal plane. Only *major* interfacial relationships are indicated; *each block bears at least some relationships to each other block;* also, industry representatives emphasize that work assignments inevitably blur the interfacial boundaries shown.

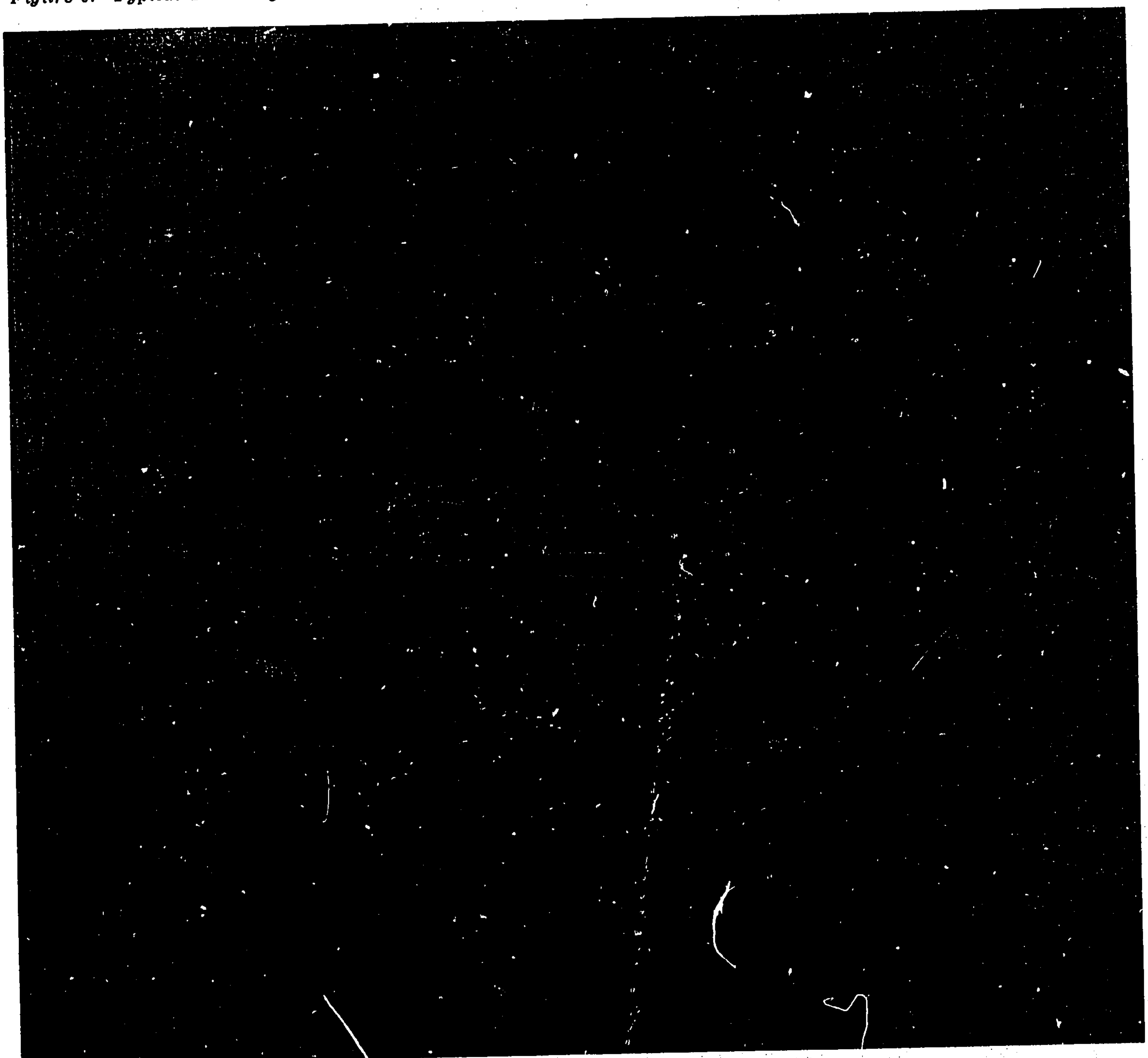
Figure 5 adds a number of additional interfacial relationships not possible on the simple diagrams of Figure 4. This diagram is to be read from left to right starting from pure science and moving through engineering into the technologies which finally interface with production. Note that science, engineering and systems management interface with mathematics, that industrial technology interfaces importantly with business administration and with engineering technology but less directly with engineering, and that business administration as well as industrial technology and engineering all interface with the management of systems although from different approaches. At the bottom of the chart it proved illustrative to list the steps of creative change initiated by research and development which interface at the left directly with science and engineering, followed by the steps of testing, pilot plant experiments and prototypes, and including more detailed improvements related to production shown at the lower right side of the diagram. There are, of course, many more interrelationships, but these would require a three-dimensional model for illustration.

Figure 6 presents for comparison purposes the "median" curricula for industrial technology and engineering technology. The curricula illustrated are not likely to be found in exact duplication in any college catalog. However, the IT curriculum approximates the median or mean suggestions of the CSC study, *50% math-science-technical content*, and in agreement with industrial preferences for breadth, *50% non-science content including management*. The ET curriculum follows closely the recommendations of the McCallick Report (see Section 3-B) which gives more emphasis to technical specialization, *70% math-science-technical content*, and which agrees with the industrial responses in the CSC Report (see Appendix A) of those companies that preferred a "specialized" curriculum, i.e., 45% of those responding to the CSC questionnaire.

Separation of ET and IT Curricula for Accreditation

The preceding analyses appear to justify concepts that the educational goals of ET and IT curricula differ appreciably and that the central IT objective of "production management" *versus* the ET objective of "support for engineering activities" will be sufficiently reflected in baccalaureate educational curricula to require application of different criteria for accreditation. If, as seems reasonable, institutional individuality can be expressed adequately within the major subdivisions of (1) math-science-technical studies and (2) non-technical studies including management, a clear-cut accrediting operation can be achieved. The real distinction between an IT math-science-technical content of about 50% *versus* an ET math-science-technical content of approximately 70% can be the main curricular criterion for

Figure 6. Typical Technological Curricula of Differing Objectives[a]



[a] Based upon curricula of 120 semester credit hours exclusive of Physical Education and ROTC.
[b] Each cell represents 6 semester hours credit, *i.e.*, 3 credits taken for one entire academic year.

separating these related educational areas. Much flexibility should then be permitted within these broad curricular subdivisions because of the diversity of employment opportunities open to each category of technologist.

The goals statement and curricular content are not the only criteria for distinguishing related educational programs. The educational and experience backgrounds for the faculty and the specialized laboratories and equipment needed for proper instruction are equally important criteria. These will be discussed as factors that can also contribute to program differentiation.

Faculty Differentiation

Faculty characteristics provide an important means of distinguishing between the purposes of educational programs in the several technological categories. Essentially all teachers above the rank of instructor in schools of engineering possess master's degrees and a majority hold Ph.D.'s. New additions to the faculty will be mainly Ph.D.'s or doctorates in engineering because of research activities and design orientation. Experience as an employment credential for engineering faculty is receiving increased emphasis, but as an addition to rather than as a substitute for the doctorate. Faculties for baccalaureate programs in engineering technology should have a majority of engineers with practical experience relevant to the curriculum. Programs in industrial technology are less dependent upon engineers for instruction and may be staffed largely by majors in industrial arts and practitioners from industry including some who have had management training or experience. Faculties of two-year technician education programs are more mixed in character and de-

pend upon the uniqueness of the program. It seems probable that faculty differentiation can and should be a major factor in distinguishing between the areas of technological education being considered here.

Types of Laboratories Required

With some exceptions, laboratories in engineering show a strong orientation toward experimentation or research, an emphasis not as important in other areas of technological training. Some engineering laboratories are used for the training of baccalaureate engineering technologists, and even more of such exchange seems useful because the engineering technologist must be prepared to work closely with engineers. Perhaps an ideal arrangement would be for the baccalaureate engineering technologist to gain a part of his laboratory training in engineering laboratories and a part in production laboratories so that he might bring to the technological team an understanding of engineering experimentation and a knowledge of practical production techniques. Laboratories designed exclusively for teaching engineering technology or industrial technology may include working models or actual production equipment not commonly found in engincering laboratories. Of course, measuring devices and testing equipment lend similarity to laboratories having quite different purposes.

Names of Curricula and Degrees

As of now (1972) very little influence for standardization of names or designations of technical curricula, programs or degrees has occurred. In this report the titles engineer, engineering technologist, industrial technologist and engineering technician are related to education programs defined in terms of length, faculty, students, facilities and curricula. Section 3-C has reviewed recommendations on terminology from previous reports. Without doubt, there are some educational programs designated in college catalogs as engineering technology that would be defined here as industrial technology, and conversely. The term engineering technology as a curriculum designation is also used for both two-year and four-year programs, a practice which will continue to be somewhat confusing. However, the graduates are usually classified as technicians, (two-year) or technologists (four-year) according to the length of the educational program and the degree awarded. Employers use their own classification systems.

No analysis was made of the names of degrees awarded to engineers, technologists or technicians. The names of degrees are determined by historical precedent or accident and are a jealously protected privilege of each institution. Efforts to develop a logical sequence of named degrees for the field of engineering have all failed. There is not likely to be any more standardization of titles of degrees awarded to technologists. The objective here is to define educational boundaries or guidelines, not to attempt to control, standardize or even influence terminology.

Section 9

Survey of Current Baccalaureate Engineering Technology Programs

While baccalaureate educational programs based on mathematics and science and designed to produce graduates for industrial employment date back at least to 1923, those designated as baccalaureate engineering technology programs were developed primarily in the last decade.

ECPD Accreditation of Technology Programs

To encourage experimentation, an ECPD committee made the following recommendation which ECPD adopted in 1966: "ECPD accreditation is based on compliance with minimum criteria established for curricula of not less than two academic years' duration. These criteria are applied regardless of the total length of the curriculum beyond the two academic years and, thus, are applicable to curricula which may lead to either the associate or the baccalaureate degree." The procedure of using the same criteria for technology programs of varying length was considered to be consistent with the procedure for evaluating engineering programs of varying length.

The first baccalaureate engineering technology curricula were accredited by ECPD in 1967. By 1970, twenty-seven curricula in twelve institutions were so accredited. In addition, ten curricula at three other institutions had received "early recognition" by the Engineering Technology Committee of ECPD as candidates for accreditation, or had reasonable assurance of accreditation when all criteria were met.

Characteristics of Currently Accredited Programs

The intent of ECPD was to permit rather wide diversification in baccalaureate programs and to provide for further experimentation. It now may be helpful to analyze the characteristics of the current baccalaureate programs which were accredited on the basis of published criteria for technology programs of two or more years in length.

The data for this analysis were obtained from catalogs and other published material, visits to the campuses of some twenty institutions, and from specially compiled data furnished by these institutions. In addition, data were obtained in the same manner from a selected group of non-evaluated and, therefore, non-accredited institutions to permit comparisons between accredited and non-accredited curricula.

Curricular Comparisons

When ECPD decided in 1966 to evaluate and accredit baccalaureate technology programs, it was anticipated that several types of educational programs might develop and, at a later date, a selection might be made of the most successful. However, the accredited and the not-yet-accredited but apparently accreditable engineering technology curricula are remarkably similar. Essentially, all baccalaureate curricula investigated utilized the additional two years for (1) greater specialization in a particular technology and (2) inclusion of some general education courses. Some general courses are frequently required by the institution for all baccalaureate graduates.

The curricula investigated ranged in length from about 124 to 135 semester credit hours, with an average of about 130 hours. Associate degree curricula range from 60 to more than 80 semester credit hours with an average of nearly 70 hours. Thus, baccalaureate curricula required about 60 semester credit hours more than associate-degree programs. Within this constraint, and after providing courses for some greater depth in the technical specialty and greater breadth in related technical courses, along with the addition of required general education studies, there was little opportunity for a concentration of other courses, such as in business or management.

Mathematics

Accredited baccalaureate engineering technology curricula had 12 to 15 semester credit hours of mathematics consisting of a course in algebra, one in trigonometry, and two courses in analytic geometry and calculus. In addition, there sometimes appeared a course in computer science, statistics, or an additional advanced math course for some technical specialty, such as electronics, that requires a stronger math background. Approximately one semester or about 12 percent of the curriculum was found to be devoted to mathematics.

The algebra and trigonometry courses were found most often to be the standard courses taken by all students. The analytic geometry and calculus courses were likely to be "applied" and developed especially for the technical students. It is not to be expected that these courses are taught with the same rigor or insistence on development of theorems and proofs as the calculus courses taught for engineering students.

Additional concepts of mathematics appeared to be taught in the technical science and technical specialty courses. Again, this was particularly true for electronics curricula, the most popular of all technology programs.

Physical Science

The requirements in basic science were found to range from eight to twelve semester credit hours or about six to ten percent of the curriculum. Generally included were two courses in physics taught with an algebra base and typical of physics courses taught for students other than those in physical science and engineering. Chemistry was frequently, but not always, required and was generally a single introductory course with a laboratory. This course, like the physics courses, was generally not developed or taught for technology students alone but included students in the non-science disciplines in other fields of study.

Technical Science

It was more difficult to identify the technical science portion of a curriculum, for these concepts may be included in courses in the technical specialty and related studies. Technical science, like engineering science, has its roots in mathematics and basic sciences. ECPD criteria for engineering curricula defines engineering sciences as follows:

> Engineering sciences have their roots in mathematics and basic sciences but carry knowledge further toward applicability . . . in engineering analysis, design and synthesis. (ECPD, 1969, p. 64).

The report of the Committee for the Development of Guidelines for Evaluation and Accreditation of Four Year Programs in Engineering Technology Education (see Section 3 B), defined technical sciences in these words:

> In these courses the technologist learns the theoretical characteristics and properties of devices, systems, structures, and processes, as well as the appropriate methods for analysis . . . mechanics, electric curcuit theory, fluid mechanics, thermo-dynamics, etc. . . .

Technical science courses may have the same or similar names as engineering science courses, but the content cannot be the same because of the difference in the amount and the level of mathematics and basic science in engineering and engineering technology curricula.

The investigation revealed that engineering technology curricula often contained three courses — nine semester credit hours, or about 7 percent of the total credit hours — in technical science. These courses were frequently limited to those that had direct applicability to the technical specialty. Breadth of coverage did not appear to be one of the objectives of the engineering technology curricula examined. Additional technical science may have been included in the technical specialty courses, but it is doubtful that the technical science content of most of the accredited baccalaureate curricula investigated was equal to 15 percent as recommended by the McCallick Report (see page 8, herein).

Technical Specialty and Related Technical Studies

Technical specialty courses consist of those in the technical major, e.g., electronics; related technical studies support this technical major, e.g., mechanical courses taught for an electronics major, or they may be intended to develop technical skills, e.g., drafting. These courses are designed to develop the ability to utilize mathematics, basic science, and technical science, including knowledge, methods, and skills in a particular field of technology.

In the curricula examined, the total semester credit hours devoted to the technical specialty and related technical studies ranged from about 40 to 55 hours, or from 30% to 42% of the curriculum. Curricula which had the lower percentage in technical specialty and related technical studies usually had a higher percentage in technical science and conversely. The difficulty of separating these areas of the curriculum suggests it may be more meaningful to combine technical sciences, technical specialties and related technical studies into one category of courses that constitute about 55 to 65 credit hours, or from 42% to 50% of the program.

General Education and Other Studies

The remainder of the typical currently accredited curriculum was found to consist of about 26 semester credit hours, or about 20%, of general studies including communications and socio-humanistic studies; and about 20 semester credit hours, or 15%, of other specified non-technical subjects and/or technical electives.

Curriculum Summary

The investigation undertaken here revealed that in 1970 those baccalaureate engineering technology programs which were accredited by ECPD consisted of the subdivisions listed in Table 6 and discussed in the foregoing paragraphs. It is to be emphasized that the 130 semester-hour program outlined is representative of current (1970) accreditation. In line with recent tendencies, it is not improbable that some 120 semester-hour programs will be proposed and accepted for accreditation. Also, in agreement with the accreditation procedure in engineering, ECPD may prefer to specify less than four years of the program, thus encouraging experimentation and flexibility in curriculum design. There is even greater justification for flexible criteria in engineering technology than in engineering education because ET curricula are administered in several colleges. The objective here has not been to specify minimum criteria but to present a picture of a typical or modal curriculum that carried accreditation by ECPD in 1970.

Technology curricula not accreditable by current ECPD criteria were found generally to contain less mathematics (in many cases, only one-half as much), about the same amount of basic

Table 6. Summary of Curricular Subdivisions for a Typical Currently Accredited Baccalaureate Engineering Technology Program (1970)

Curricular Area	Semester Credit Hours	Percentage of Total Hours
Technical Sciences, Technical Specialty, and Related Technical Studies	60	45%
Mathematics	15	12
Basic Science	10	8
General Studies	25	20
Other Specified Non-technical Courses, e.g., ROTC, and Technical Electives	20	15
TOTAL	130 sem. hrs.	100%

science, considerably less technical science and somewhat more technical specialty or related technical courses than accredited programs. The additional emphasis on technical courses often appeared designed to develop a higher order of technical skills, such as drafting. The other specified courses, which may have constituted 20% to 25% of the curriculum, were often business and management related courses. Such extreme variations are not usually termed *engineering* technology.

Faculty Characteristics

The characteristics of the current faculty at institutions with accreditable engineering technology curricula varied widely from institution to institution and tended to reflect the origins of the program. If the background was Industrial Arts Education, many faculty members had education degrees including some doctorates. If the program grew from a former technical program or vocational-trade program, some of the faculty were craftsmen without collegiate degrees. If the technology program was closely allied to or was split from an engineering program, many of the faculty were engineers with B.S. and M.S. degrees. Newer members of the faculty may have had a B.S. in technology and an M.S. in technical education. There were nearly always a few faculty members with degrees in mathematics, physics, chemistry or other sciences.

Proportion of Engineers on the Faculty

Because engineering technology curricula are designed to produce technologists "in support of engineering activities", some engineers are considered essential to teach the technical science and specialty courses. The 1962 report, *Characteristics of Excellence in Engineering Technology Education,* states: "It is the Committee's opinion that approximately half the faculty members teaching the technical specialties should be graduate engineers or the equivalent." This recommendation, which is not a part of current ECPD criteria, has apparently not been followed by all institutions with accredited engineering technology curricula. However, it is noted that recent additions to technology faculties have tended to be weighted heavily with engineering graduates. Thus one may expect this recommendation to be achieved within the next several years. The engineering "flavor" of the technology curricula investigated appeared to be related to the presence of engineers as faculty members, because other technology programs taught by faculty without engineering degrees were observed to be of a different character.

The "Excellence" report cited above states: "A significant proportion of the faculty must have relevant industrial experience, reasonably current." A review of the biographies of the faculty from some of the institutions without a long technical tradition discloses that this recommendation is sometimes more a hope than a reality. It should receive increased consideration.

Students' Aptitudes

The accredited baccalaureate engineering technology programs for which data were available attracted students with about the same range of academic aptitudes, measured by standardized tests, as other college freshmen and transfers. As a whole, technology students suffer by comparison in academic aptitudes only when measured against engineering students.

While the average score varied slightly from institution to institution, the mean score of the averages of entering students of all institutions was about 22 on the American College Testing (ACT) program or about 1000 on the Scholastic Aptitude Testing (SAT) program. Entering engineering students at some of these same institutions had a mean score of about 25 on ACT or about 1100 on SAT. One implication of test scores of entering engineering technology students that places them with the average of all entering students in the institution is their apparent ability to complete successfully standard or all-university courses in mathematics, science, communications, and socio-humanistic subjects.

The academic potential of entering engineering technology students, and the rigor of program that eliminates the less able, indicates that students of low academic potential in other curricula probably would not be successful in bachelor's programs in engineering technology. A possible exception may be transfers from engineering curricula. Data from two institutions indicated that low achievers in the engineering program transferred in small numbers to the engineering technology program and most were successful in completing the technology program. However, transfers from all curricula represent only a small fraction of registrants in engineering technology. An exception, of course, is the rapidly growing number of transfers with associate degrees from junior college technical programs.

Student Interests

No statistical data were obtained that would measure the interest patterns of engineering technology students or differentiate their interests

from engineering students. Both engineering and engineering technology educators stated that the technology student had a greater interest in "hardware" or equipment and consequently in laboratory and technical skills. However, it appears that it will take especially knowledgeable and competent teacher-counselors or admissions advisors to differentiate between potential engineering and engineering technology students. At the moment, aptitude in science and achievement in mathematics appear to be more reliable indicators than interest patterns in machines, structures or electronics.

Laboratory Equipment and Other Facilities

No adequate data were found that would permit meaningful comparisons of laboratory equipment and facilities between various kinds of technology programs or between technology and engineering or physical science programs. Square feet of laboratory space, value of equipment, and other data usually submitted as part of the evaluation for accreditation vary so widely from institution to institution — even for similar programs — as to be essentially useless for differentation.

A qualitative evaluation of the technology laboratories visited indicated that, in general, they were oriented more toward production or testing than toward research or experimentation. Because of the perceived need to develop technical skills, there frequently were extensive production or shop laboratories and large drafting rooms. With commercially manufactured laboratory equipment becoming increasingly available, there appears to be a small trend toward more standard experimental or demonstration laboratories in technology programs.

Placement of Graduates

While educators struggle with precise definitions and descriptions of educational programs, employers and employees in industry and professional practice apparently see engineering as a wide spectrum of activities encompassing a wide range of positions. The 1960 census recorded over three-quarters of a million persons who classified their occupation as engineer even though more than one-third of them had only a high school education or less. Similarly, employers classify many positions as engineering positions although the incumbents often are not engineering graduates.

A number of institutions were requested to furnish the titles of positions offered to their baccalaureate engineering technology graduates. The data supplied indicated that about three-quarters of the graduates were offered a position with the word "engineer" in the title. Examples of titles were junior engineer, engineer trainee, sales engineer, customer engineer, maintenance engineer, and manufacturing engineer. Essentially the same titles are used by industry for engineering technology graduates as for engineering graduates for beginning jobs. An examination of the titles of industrial positions offered hundreds of baccalaureate graduates from a number of institutions did not disclose a single title using the words "technician" or "technologist," although these titles do appear in descriptions of certain civil service positions.

Section 10

Desirable Characteristics of Baccalaureate Engineering Technology Programs

Goals and Objectives

The overall educational objective of engineering technology education is stated in Section 5 as follows:

> Engineering technology education is designed to educate two-year, associate-degree engineering technicians and four-year, bachelor-degree engineering technologists either to assist engineers or to provide independently the support for engineering activities....

The technologist with a baccalaureate degree receives a more intensive education than the technician in his technical specialty, an education of more breadth because of the two additional years, and of greater depth made possible by additional courses in mathematics and technical sciences. He is capable of independent action in performance of technical activities and is, therefore, often found in supervisory positions over technicians and draftsmen. His background in general or liberal studies equips him for positions in technical sales and other positions in which skill in public contacts is desirable. The engineering technologist performs many of the same kinds of activities as the engineer but at a different and often later stage in the progression from concept to product.

The engineering technology educational program has the same elements as the engineering educational program: mathematics, basic science, technical science, technical specialty and related technical studies, communications and socio-humanistic courses. The essential curriculum content, mathematics and basic technical science, is not of the same rigor or depth as in engineering. Therefore, only the activities in the field of engineering (including design) that do not require a sophisticated math-science background can be performed independently by the technologist. This is the thought that lies behind the statement "to assist engineers or to provide independently the support for engineering activities."

Desirable Characteristics of Baccalaureate Engineering Technology Curricula

The engineering technology study has clarified the need for curricular flexibility, especially at the baccalaureate level. A suggested curriculum guide for a baccalaureate engineering technology program is given in Table 7.

The Advisory Committee in arriving at the recommendations in Table 7 generally accepted as desirable the curricular subdivisions used previously in Table 6 and Figure 6 but found it necessary to provide ranges to encompass certain highly specialized curricula such as electronics engineering technology. It will be recalled that Table 6 represents curricular subdivisions of a typical baccalaureate engineering technology program as currently accredited by ECPD and that Figure 6 illustrates a median curriculum based upon the industrial survey of the California State Colleges Study of 1970 and the McCallick report of 1966. Recognizing the severe inter-disciplinary problems facing society in the 1970's, the Advisory Committee recommends achievement of the maximum practical breadth in curriculum design. The elements of the suggested guide of Table 7 are discussed in the following paragraphs.

Table 7. Ranges of Time Allocation Recommended for Four-Year Engineering Technology Curricula

Mathematics. The approximate one-half academic year of mathematics should include college algebra, trigonometry and selected topics in analytic geometry and calculus. Other subjects in mathematics, statistics, or computers may be included when needed to strengthen the foundation for subsequent technical subjects.

Basic Science. The approximate one-third academic year of physics and chemistry or other natural sciences should be at a level consistent with the objectives of the program. Although science requirements have usually been limited to physical sciences, an increased interest in life science or environmental science is anticipated. The study of basic sciences should add to the foundation for subsequent technical courses.

Technical Studies. Approximately two years of the four-year program may be devoted to the technical sciences, technical specialty and related

technical studies. The technical sciences, like the engineering sciences, have their roots in mathematics and the basic sciences. They should provide the avenue for understanding the theoretical characteristics and properties of devices, systems, structures, and processes, as well as the appropriate methods of analysis. They should *not* be limited to those courses having a specific relevance to a particular technical specialty. The technical specialty courses and courses that support the technical major should enable the graduate to interpret, in practical terms, the results of engineering analysis and/or design. They should be up-to-date in the current state of the art in a particular technology. They should provide a basis for the graduate to distinguish between sound and unsound practice.

Non-Technical Studies. The approximately one academic year devoted to the area including communications, humanities, social sciences, and electives outside the major should reflect and be consistent with the institution's general educational objectives. Within this allocation, a limited sequence of management-related courses may be included. However, the objective of breadth is compromised if such courses are themselves essentially technical.

Upper Division Work. To qualify as a baccalaureate curriculum, at least one-third of all the courses in the curriculum, excluding unrelated requirements such as physical education but including courses in the technical specialty, should be upper division courses. Upper division (third and fourth year) studies are generally those which require either lower division (first and second year) work as a prerequisite, or the mastery of a body of knowledge necessary to understand and successfully complete the upper division studies.

Degree Designation. It is recommended that the degree designation for the curricula include the term "engineering technology," although it is clearly recognized that curricula with other names and degree designations may meet or exceed the recommended minimums and be a part of the family of engineering technology educational programs.

Admissions to Baccalaureate Programs

The admission requirements for entry into the baccalaureate engineering technology curricula at either freshman or junior-transfer level should not be lower than the general admission requirements to the institution of which the technology program is a part. Technology students should have the experience of competing successfully with other university students, but not usually with engineers, in mathematics, basic science, communications and socio-humanistic subjects.

Because the beginning mathematics course in an engineering technology curriculum is college algebra, the entering student should demonstrate proficiency gained by high school study of algebra and plane geometry for a total of at least two years as a prerequisite for enrollment in this program. Credit earned in remedial study should not be used to fulfill the criteria for an acceptable engineering technology curricula.

High school courses in chemistry or physics, while not now generally required for entering technology students, are highly recommended.

Faculty for Baccalaureate Programs

It is axiomatic that faculty members should know more about the subject matter they are teaching than the students are expected to learn. This is self-evident for courses in communications, socio-humanistic subjects, mathematics and basic science. Technical sciences, the technical specialty and related technical courses — drawing as they do on mathematics and basic science — require faculty members who have mastered mathematics through rigorous courses in differential and integral calculus, who have a comprehensive knowledge of fundamental science and technical science based on this higher level of mathematics, and who have an advanced knowledge of their technical specialty acquired both by advanced study and relevant experience. It is recommended that one-half of the faculty teaching the technical sciences, technical specialties, and related technical studies should have at least one degree in engineering (or engineering technology with added science and mathematics) in order to teach their subjects with the necessary dimension of demonstrating technological relationships to engineering activities. Further, because technologists are expected to be immediately useful to their employers, all faculty members teaching the technical specialty courses are expected to have had sufficient recent and relevant professional experience to train the student in the current practices and requirements of industry.

Faculty members teaching the technical skill courses are not required to have advanced degrees but are expected to be artisans or masters of their crafts. However, they should represent only a small fraction of the total technology faculty.

Baccalaureate engineering technology education, with its emphasis on problem courses, participation laboratories and technical skills, requires a sufficient number of faculty to provide adequate attention to each student. The student-faculty ratio for technical courses will vary, depending on the nature of the curricula and courses, but should not exceed the institutional ratio for those science related areas for which research is not a major factor. Student-faculty ratios for non-technical studies should follow the institutional pattern because most of these are courses offered to students majoring in many disciplines.

Supporting Facilities

It is particularly important that instruction in baccalaureate engineering technology be conducted in an atmosphere of realism. Theory courses should be strong in problem identification and solution, with emphasis on the quantitative, analytical approach. They should be accompanied by coordinated laboratory experiences, including the measurement, collection, analysis, interpretation and presentation of data. Laboratory equipment should include types that would be encountered in industry and practice. Since one of the objectives of engineering technology curricula is the development of technical skills, each student should be thoroughly familiar with the use and operation of the analytical or measurement equipment common to his major field of study. An experience in the operation of standard or basic shop equipment — lathes, welders, engines — does not alone meet this requirement.

Equipment catalogs, trade magazines, and journals of industrial processes and practices should be readily accessible and used by the baccalaureate technology student in addition to the usual library resources. The student should be familiar with the literature of his technology and encouraged to use it as the principal means of staying abreast of the state of the art in his technological field.

The computer has become one of the most important and versatile tools in engineering practice. The baccalaureate technologist as a part of the engineering team must acquire an understanding of its capacities and limitations in his field of technology, and should develop some facility in its use for solving problems. Technology students should have access to digital computer equipment, and use computers to acquire the knowledge and skills described here.

The baccalaureate engineering technologist is not expected to require a long period of training by his employer before becoming a useful member of the engineering team. Therefore, his education must be conducted in appropriate classrooms, laboratories and other physical facilities by a faculty adequately experienced in practice and supported by non-academic personnel.

Section 11

Practical Engineering *versus* Engineering Technology Programs

The advent of four-year baccalaureate curricula in engineering technology has led individuals and technical societies to express concern over the scientific orientation of modern engineering curricula. Without attempting to review history we may refer the reader to the ASEE report of 1955 on *Evaluation of Engineering Education* and the ASEE *Goals* Report of 1968, both of which recognized the need for a strong mathematics and science background in modern engineering curricula. In fact, one would have to consider curricula in use before 1920 to find examples that failed to include a rigorous study of mathematics through calculus, classical physics, and chemistry, which in total represented at that time about one-fifth of the curriculum. The math-science percentage now seems to have grown to about one quarter of four-year engineering curricula in response to the increased sophistication and extent of modern science and technology.

For a period of several years before and after 1960, the need for additional mathematics and science in engineering education was accomplished largely by lengthening curricula until they demanded more nearly five years of study than four. The recent trend to reduce curriculum length to a realistic four years without loss of mathematics and science background has squeezed down the practice-oriented courses for the bachelor's degree. It remains to be seen whether future master's degrees in engineering will provide additional training in design. With the aid of computers, design studies can be educationally more sophisticated than the routine practice courses of 1950-60. These evolutionary changes in engineering curricula have been accompanied by the development of baccalaureate curricula in engineering technology and other technology.

Practical Engineering Curricula

There have always been some baccalaureate engineering curricula that diverge from the norm by placing increased emphasis upon engineering practice at the expense of either math-science or humanistic-social studies. Such curricula have not been particularly popular with students. In fact, over many years the most theoretical or mathematical curricula, electrical or electronic engineering, have had the highest enrollment of students; and a recent wave of popularity has produced considerable enrollments in systems engineering, another mathematically-oriented curriculum. Also, students press for admission to engineering colleges that are highly science oriented. The thought, therefore, that practical orientation of certain engineering department curricula might attract a new wave of students is not backed by extensive previous experience although one or two exceptions have been called to our attention.

The inherent problem is a tacit understanding of long duration that a rigorous study of calculus, physics and engineering science represents a minimum essential for the education of every engineer. There is a limited number of high school graduates who prepare themselves with the full set of prerequisites for engineering study and who are equally prepared for the rigor of such study by commitment to become engineering professionals. The group may be divided between several engineering departments and/or subdivided between theory and practice, but the total number of enrolled students in engineering on a national basis seems unlikely to be influenced significantly. On the other hand, reduced math-science requirements in college (along with reduced high school math-science prerequisites) acceptable for the study of engineering technology at the baccalaureate level, opens up a much larger pool of high school graduates as possible registrants. There is no reason, therefore, for concern that the growth of technology programs may seriously reduce enrollments in engineering.

The competition of other professions and of new paraprofessions which will be discussed in the next section will be more influential in restricting engineering enrollments. The growth of industry and particularly its increased technological sophistication should provide for employment of all available new engineering graduates in a period when the growth of college enrollments is slowing down and engineering enrollments are on a plateau or possibly a declining curve. A somewhat parallel case, the development of several para-medical professions since 1960, has not reduced applicants for the study of medicine.

Transferability of Knowledge

The industrial interest in practical engineering graduates, who will be immediately useful upon employment, conflicts with the objective of making the years in college as productive as possible in terms of training that will have a low degree of obsolescence. Mathematics, English, basic science, engineering science and analysis have a high degree of transferability to many jobs and a low degree of obsolescence. It seems likely that these characteristics will continue to be emphasized by a large majority of engineering colleges. In contrast, technological curricula are designed for greater specialization and immediate usefulness of the graduates. The cost of specialization is reduced transferability of the graduate from field to field and the probability of earlier obsolescence unless continuing education occurs.

To counteract the approach of obsolescence of its graduates, the engineering technology faculty needs to develop the student's confidence that he can continue to learn throughout a lifetime of employment, both by enrollment in formal programs and by his personal study.

Trade-off Between Theory and Practice

There is an inevitable trade-off between transferability of knowledge and immediate usefulness in employment. Among industry's needs for all kinds of well-educated technical manpower, broadly trained engineers and specialized engineering technologists represent related but distinctly different educational products. It is not possible for one type of baccalaureate engineering curriculum or branches of a single four-year curriculum to serve the contrasting objectives of scientific breadth and technical specialization. The Advisory Committee of the Engineering Technology Education Study, therefore, has concluded that although some baccalaureate engineering curricula reorganized to place increased emphasis upon practice might serve usefully in a particular institution, the much greater need is for graduates of engineering technology programs at both the associate and baccalaureate degree levels.

Human Source Material for Engineering Technology Education

General Patterns of College Attendance

Currently, approximately 68% of American young men in the 18-24 age cohort may be expected to attend a college or other post-secondary educational institution. Typical data are as follows: 40% enter a four-year college; 12%, a two-year college; 3%, a technical institute; 1%, a business college; 4%, a trade or apprentice school; and 8%, an armed forces school (Flanagan, 1966). The proportion of students in technology programs is relatively small. Estimates are that only about 100,000 of the 4,400,000 males enrolled in higher education programs are studying engineering technology or related subjects. This is only 2.3% of the cohort. Moreover, about 20-30% of all students in higher education (and more in technical programs) drop out, so that fewer than 2% of the college age group graduate with specific education as technicians.

Career Preferences Expressed by High-School Males

High school senior boys, when asked to express a preference for a career do not usually give engineering technology a high priority; Table 8 lists the expressions of choice made by high school seniors in one extensive study (Flanagan, 1964). It is noted that only one percent of the responses included "Engineering or Scientific Aide." On the other hand, the expressed preference for "Engineer" is remarkable. It is doubtless considered a professional or prestige title.

It is interesting to note that a substantial proportion (48%) of high school boys tend to plan careers in professional or technical fields, even though manpower utilization studies indicate that only 15% of employed males in the 25-29 year age group work in such fields. Accordingly, because of the rigor of the educational program and other factors, it appears that only one-third of the high school graduates who so aspire attain planned careers for which a technical or professional education is necessary.

Characteristics of Students in Technical Programs

It is revealing to study the distribution of socioeconomic level and academic ability level of students who recently were enrolled in technical programs. Table 9 displays the data, where entries in the table are the percentages of the total male cohort belonging to each cell. For example, 5.3% of all males in the upper half of the socioeconomic spectrum and in the lower half of the ability spectrum attended a technical institute.

Table 8. Career Preferences Expressed by High School Males in One Study of Occupational Choice[a]

Career	Percentage Preferring Career[b]
Accountant	4.4%
Biologist	1.6
College Professor	0.7
Engineer	18.2
High School Teacher	4.6
Lawyer	4.1
Physical Scientist	3.5
Business Man	5.7
Physician	3.0
Craftsman	1.1
Engineering or Scientific Aide	1.0
Farmer	3.9
Skilled Worker	6.2
Structural Worker	1.5

[a]Adapted from *Project TALENT, The American High School Student* (Flanagan, 1964)

[b]Total does not add to 100%; illustrative data only are reported.

It is also interesting to compare four kinds of scientific-technical workers (i.e., research scientists, engineers, technicians, other technical workers) with each other and with other occupational groups. A possible result is the identification of traits most likely to be associated with individuals in various occupational areas.

Table 9. Distribution by Socioeconomic/Ability Cells of the Percentage of College Age Males Enrolled in Technical Institutes.[a]

	Lower Half, Ability Level	Upper Half, Ability Level
Lower Half, Socioeconomic Level	2.5%	2.3%
Upper Half, Socioeconomic Level	5.3%	1.7%

[a]Adapted from *Project TALENT One-Year Follow-up Studies* (Flanagan, 1966).

The four categories of technological workers just mentioned have certain characteristics in common which distinguish them from the population as a whole. For example, they all score high on tests of visual reasoning, they are somewhat less interested than the "average person" in business matters, they display marked interest in outdoor or shop-related activities, they have a significant lack of cultural interests, and—predictably—their "science interest" scores on psychological tests exceed the population mean by at least one standard deviation.

Discriminating Characteristics

The factor which seems best to discriminate between these four groups of technological workers is, predictably, mathematics aptitude and achievement. Research scientists have for this factor a group mean which is 3.4 standard deviations above the population as a whole, at the 99.9 percentile level. Engineers score at the 98 percentile level, technicians at the 82 percentile level, and other technical workers only slightly above 50, the population mean. Verbal aptitude is also a dis-

criminating factor. Research scientists and engineers score at about one standard deviation above the mean. Technicians score at the mean, unschooled technical workers below it. "Sociability"—an indicator of interest in people, organizations, and group activities—is another interesting discriminant; both research scientists and engineers score below the population mean on this trait, while technicians and other workers score at the mean.

Observations

Consideration of the historical patterns of college attendance, typical patterns of career aspirations, and general characteristics of students in technical programs leads to the following observations regarding human source material which may have relevance to educators in the domain of engineering technology programs:

1. Normal selective admissions policies in educational institutions may eliminate many individuals who might succeed in engineering technology programs at the associate-degree level, and highly selective admissions policies may eliminate potential students for the baccalaureate technology programs. Potential students for associate-degree programs may appear not to be "academically inclined", often coming from the lower half of their classes. Sufficient data are lacking on a minimum acceptable level of previous achievement for potential baccalaureate-degree students of engineering technology.

2. Students are apt to be disinterested in English and sociocultural matters; great skill must be used to introduce such vitally needed subjects into the curriculum in such a way that they are accepted by students as important to their future careers.

3. Because research scientists, engineers and technicians have similar attributes in all but a few areas, the counseling task is extremely difficult.

4. Career aspirations of boys tend to fall in technical areas; routes to satisfy such aspirations at levels socially acceptable should exist in order to capitalize on such motivations.

The High-School Pool of Technical Interest and Talent

As the mathematical (or theory) demands of science and engineering education have risen over the past decade and a half, the percentage of college students majoring in these fields has steadily declined. When it became clear that attractive careers could be had in social fields where the requirement for a rigorous study of mathematics and physics was nonexistent, an increasing percentage of students has passed up the hard sciences and engineering. Efforts to recruit more students into science and engineering during the upper high school years have been unavailing. A recent survey published in the *Journal of Chemical Education* (Snelling and Boruch, 1970) clarified the fact that close to one-half of students who choose to major in science in college have made that basic decision before entering the ninth grade and over three-quarters had so decided before entering grade eleven. It seems likely that the general interest in a scientifically-oriented career *versus* one less technical is developed in pre-high-school years.

It is the belief of the staff of the Engineering Technology Education Study that the rigorous study of calculus followed by the equally rigorous courses in physics required historically of all engineering students represent a barrier to increased enrollments that can and should be lowered for engineering technology students. The work of the technologist is usually not sufficiently involved with science and engineering theory to require more than an introductory problem-oriented approach to calculus. This limitation in itself will also limit the rigor of the physics course to well below that of engineering physics. The result should be to attract students who find practical application of science intriguing but who have not prepared themselves for admission to engineering study. This pool of students may be as large as or larger than the pool of potential engineers.

The Influence of Market Demand

Market demand for students graduating in a particular specialty within a field such as engineering or engineering technology may influence the choice of specialty by students. However, market demand at the time of baccalaureate graduation is displaced by six to eight years from the junior high school years when choice of broad field of employment along with decision to prepare therefor may be made. Hence the current demand for baccalaureate graduates in a broad field such as engineering technology has little effect upon the number of students selecting the field itself. Further, students who have committed themselves to a field as early as junior high school are unlikely to change that commitment because of reduced demand or current increase in demand in another broad field.

Competition for Professional Talent

Engineering educators seem confused and frustrated by the reduced interest of freshmen in becoming engineers. At one time the engineering interest level, measured by the percentage of college freshmen enrolled in engineering, was double that of 1970 and this percentage apparently is still reducing. The explanation is quite simple; there is an increasing competition from other and newer professions. At one time the bank teller, the store manager, the insurance adjuster, the bond salesman, the civil servant, the social worker and other benefit administrators were all self educated beyond high school; most are now college graduates along with a hundred other careers or paraprofessions. It seems doubtful that engineering can again obtain both quantity and choice of quality among high school graduates. To maintain essential capacity of graduates at the level necessary for engineering planning, design and supervision, engineering schools must continue to employ selective admission at the freshman, junior-transfer and graduate levels. The obvious corollary is that the engineering profession must accept the aid of increasing numbers of paraprofessionals to help carry out the plans it is responsible for creating and initiating.

Section 13

Assessment of Strengths and Weaknesses of Engineering Technology Education

Educational strengths and weaknesses involve matters of opinion. One way to measure strength is to match accomplishments with goals. In a distinguished university, a program that attracts only mediocre students, may appear as a weakness. The same program in a community college may be achieving a stated goal. In fact, the value of a program is very difficult to determine if there are no clearly expressed goals or if definitions are confused. An area of ambiguity for the entire field of technology is the careless use of the two words "engineering" and "industry" and their adjectives to describe technological education and its graduates. Publications have been found that group together under "engineering technician education" programs that range from vocational training to rather scientifically oriented curricula in electronic technology. Agencies, in particular ECPD, need to sharpen their definitions. Some aid is provided by this report.

Diversity and Differentiation

Another problem of coordination exists because of the diversity of institutions involved in different areas, levels or types of technological education. Elsewhere has been described a variety of institutions including non-profit technical institutes, profit oriented institutions, public vocational-technical institutes, public and private junior or community colleges, engineering colleges, separate colleges of technology, etc., as centers for technological education. Any accreditation operation that encompasses such a diversity of institutions must be far more flexible than one designed for engineering, architecture or law where the educational units are more uniform in their objectives and in their curricular patterns. Evaluation or accreditation acceptable to institutions of great diversity must be approached with full recognition of this factor of variability.

It should become a strength of technological education that baccalaureate institutions have begun to differentiate their programs between engineering technology and industrial technology. To the extent that these terms are used to indicate different levels of math-science-technical content and a different degree of emphasis upon non-technical areas, including management, they will provide students with a choice between career objectives. These objectives might be stated as (1) close association with the engineering process with continuing growth of technical competency *versus* (2) close association with the production process with increasing attention to economy and supervision. Of course, personal factors are often more important in advancement than education. Hence, cross-overs occur. However, in curriculum design and faculty selection, a pattern is set that attracts or repels students based upon program goals and student objectives. A clear statement of program goals should reduce the percentage of mismatches with student objectives, even though the latter are seldom expressed clearly.

Experience and Experimentation

One type of strength in any area of education is that of experience. Engineering technology education is fortunate in that there are a number of institutions, mainly awarding the associate degree, that have evolved over half a century from vocational schools into rather strong technical institutes. Usually these institutes have kept in touch with their graduates and with industry. They have continuously changed and also lengthened their programs to meet the needs of industry both as expressed by industrial representatives and as experienced by their alumni. Their faculties have a much higher percentage of graduate engineers than is common for the technical programs of the community colleges. Their curricula offer a high percentage of math-science-technical content including extensive use of modern instrumentation and equipment. Some of these institutions have greatly influenced the ECPD accrediting procedures for associate degree programs. Their influence has been on the side of technical strength closely related to engineering. Since the graduates of two-year technical institutes do not compete directly with graduate engineers, the colleges of engineering have usually encouraged and cooperated with the technical institutes.

Another type of educational strength is the willingness to experiment with new or revised programs. The many new institutions and new programs in the technological field provide the opportunity for wide experimentation. The reentrance of profit-oriented corporations into the field of technical education, where many traditional institutions find themselves in financial difficulty, is clear evidence that new instructional techniques are being planned or are under trial. Cost-effectiveness measures will be developed and applied by profit-conscious administrators. If successful, these procedures will be emulated by other types of technological institutions, colleges or departments. A great deal of experimentation and innovation is doubtless being encouraged by federal grants as is true in other fields of education. Given time, new strengths should be developed because of the opportunity for experimentation that accompanies new entrants into the field of technological education.

Influences of Status and of Faculty Backgrounds

The importance of social status in American Society and the desire for professional recognition has drawn some technological faculties into the delusion that they should emulate engineering programs. This desire may be stimulated by the appointment of a large percentage of graduate engineers to engineering technology faculties. It leads to requirements in math-science that seem in catalog descriptions to be comparable to those in engineering curricula; however, such subjects cannot be taught with engineering rigor without restricting the pool of student applicants to pre-engineers. A justification for this approach might be in planning a transition from an engineering technology curriculum to one of engineering. However, the present industrial market would seem to indicate that a reverse transition of some of the less popular engineering programs into engineering technology programs would be more logical. A viable engineering technology program needs its own goals which should be distinct from those of a related engineering program.

A weakness in many associate-degree programs is the residual faculty of vocational background retained from an earlier vocationally-oriented program. This situation for baccalaureate institutions is most likely to exist in technology programs that are evolving from industrial arts education. Faculty strength can be built by gradually changing the character of the curriculum into one of increased emphasis upon the math-science-technical areas while recruiting faculty of high competency for teaching these subjects. Fortunately for institutions that face this problem, new baccalaureate programs in engineering technology and also industrial technology have proved so attractive to students that rapid growth of the faculty has been the common experience.

Student Strengths and Weaknesses

A strength that was found in the baccalaureate technological institutions or departments studied was that the engineering technology students compared favorably on the basis of tests and grade level with students enrolled elsewhere in the institution. They only suffered by comparison with engineering students in those institutions having a college of engineering. Hence, as compared to all college students the four-year engineering technologists are in no sense inferior students. They need not be compared with students of physics or engineering who have different objectives. In general, engineering technology students find no unusual difficulty in competing with other college students in courses required of all students, that is, a core of general education.

At the level of the individual department or program, for two-year engineering technology, there is often a weakness in student achievement based upon a policy of open admission and elective courses. It is generally admitted that the percentage of all technical students who graduate with associate degrees is low. This is especially true for the community junior colleges. One possible reason why many students take the more vocationally-oriented courses but avoid others considered essential for the associate degree is that some educators defend this as a laudable achievement for those students who do not have adequate motivation to complete the program. It is an open question whether a more definite requirement that each student enroll each term in one or two courses required for the associate degree might build confidence and interest and improve degree completion. This is obviously an area for increased experimentation.

The Continuing Value of Past Studies

A strength observed in engineering technology education today is that it has had guidance from several past studies that received rather wide attention. The ASEE study of 1962 for associate degree programs, entitled *Characteristics of Excellence in Engineering Technology Education*, provided definitions and recommended educational levels that have received wide acceptance. It recommended that one-half the faculty teaching the technical specialties be engineers, suggested admission requirements and drew up curricular guidelines. It may have been overly rigorous in its standards for many community junior colleges, but it provided a goal that has doubtless influenced a large portion of all technological programs. The fact that the modal associate degree engineering technology program of 1970, determined from a study of 120 curricula, corresponded very closely with the recommendation in the 1962 document (see Table 4 herein) is evidence that guidance has indeed occurred. More recently, the 1966 report on *Recommended Guidelines for Evaluation and Accreditation of Four-Year Programs of Engineering Technology* has greatly influenced the growth of baccalaureate engineering technology curricula. The "Interim Criteria for the Accreditation of Baccalaureate Degree Programs in Engineering Technology" adopted by ECPD in 1970 is having an impact on the development of such programs.

Section 14

Conclusions of the Engineering Technology Education Study

From the comments received since publication of the *Preliminary Report*, it is clear that there is a widespread desire for guidance leading to actions that might be taken. Agencies that will influence the production of technicians and technologists are at least the following:

1. The junior and senior high schools in terms of curricular choices and career guidance.

2. The private technical institutes that have helped establish a strong standard of technical competence for associate degree technicians.

3. The large number of public community junior colleges and technical institutions that offer both college-transfer curricula and technical studies that are primarily job-oriented but are not excluded from college transfer.

4. Colleges of engineering, several of which have developed baccalaureate technology curricula, either for four years or for the upper two years.

5. Colleges of technology, a few of which have operated successfully for a decade or more in awarding four-year baccalaureate ET degrees.

6. Colleges of education, agriculture, architecture and others that have offered technological degrees, usually not designated as engineering technology, such as building construction, mechanical agriculture and industrial technology.

7. The technical engineering societies that will encourage or discourage the education of more technologists by their procedures of admission to membership.

8. The interdisciplinary engineering societies, including ASEE, ECPD and NSPE, that influence public attitudes by recognition and accreditation.

9. Industry, civil service, and organizations that represent the employers for a majority of technicians and technologists and that influence both students and educational institutions through the medium of employment.

10. Certification and registration boards that exist for technicians and engineers and which will soon face the desire of technologists for recognition.

Majority Viewpoints

There seems to be a consensus that for the next movement upward in production, industry will need an increased input of technicians and technologists. Based upon a Bureau of Labor Statistics Report of 1970 (see Appendix B), it is estimated that of approximately one million technicians now employed, about two-thirds perform work related to engineering activities. However, only a quarter seem to have as much as two years of post-high-school education directed toward their employment. A large number of technicians (estimated by BLS at 1,200,000) will be sought by industry, government and other employers between 1966 and 1980. This need will be partly engendered by volume of product, but it is being enhanced by growing sophistication of equipment and processes that demand more than vocational skills for construction, installation, operation, production and maintenance. Technologists will also be used for standardized design, in sales, and in supervision of production, including opportunities in management.

Competition in Employment

In some of these areas, technicians and technologists will compete with engineers. However, the engineer's background of science and his capacity for overall design will continue him in a commanding position both in relation to the solution of complex technical problems and in management where complex engineering operations are involved. Both engineer and technologist must compete with the graduates of other disciplines in management areas where problems other than technical ones are controlling.

Engineering educators facing static or declining enrollments, some unemployment among engineers and reduced job offers to graduates in 1970-71 would be more pleased to see an increase in associate degree technicians than in baccalaureate technologists. Nevertheless, most engineering educators recognize that the growth of baccalaureate programs in technology will extend over a decade or more. Furthermore, it seems likely that industrial growth, together with greater utilization of technically educated personnel will provide ample opportunity for both engineers and technologists in the future.

In retrospect, it appears fortunate that engineering enrollments in scientifically-oriented programs failed to grow in proportion to general college enrollments after about 1955. Otherwise, engineers would now be serving extensively as technicians and the public's concept of the engineering profession would be even more confused than it is. Large numbers of overeducated technicians or technologists would represent frustration for both employer and employee and would probably generate serious discontent, reverberating back into the university system.

Curricular Differentiation

Engineering technology curricula generally require one or two years less preparation in high school mathematics and a lesser science background than do engineering curricula. Engineering technology students normally complete college-level studies of mathematics and science with a different orientation and less extensive theoretical study than engineers. These courses may also be of an applied nature. Hence in the technical science and technical specialty subjects, professors teaching technology cannot probe to the same

depth in theory as engineering professors but must give greater emphasis through laboratory and skill courses to established methodology and practice. These variations are quite adequate to differentiate between the education of the engineering technologist and the engineer, but they are enhanced by the backgrounds and interests of the separate faculties. Engineering faculties are composed of a high percentage of engineering doctorates with research capabilities while engineering technology faculties, desirably composed of about one-half engineers, have fewer advanced degrees but include a much higher proportion of teachers with extensive industrial or other practical experience. It is recommended that these differences be recognized as a desirable contribution to coverage of the entire technical field.

Differentiation from Industrial Technology. Baccalaureate engineering technology programs must also be differentiated for purposes of accreditation from other technology programs. Some of these others, usually termed industrial technology, may resemble engineering technology, but their more common formulation is of a different character, often described as broad rather than specialized. The mathematical content of many four-year industrial technology curricula may be terminated without any study of the calculus. The basic science requirement may be less than for engineering technology, and there are likely to be few, if any, technical science courses. The main thrust of such a program can be only indirectly related to scientific or engineering theory. Instead, it is usually pointed toward familiarizing students with methods, machines, skills and techniques of production or construction, and it always emphasizes industrial or personnel management. Considerable attention may be given to drafting as a means of technical communication. In general, the median for math-science-technical content of IT curricula is usually only about 50%, leaving an equal emphasis upon non-technical studies including business and management which form an important distinguishing feature. In contrast, the median for math-science-technical content of ET baccalaureate curricula is approximately 70%, leaving 30% for non-technical, mainly communication and liberal studies, with only limited time available for management courses. The math-science-technical content is found to be about 80% of two-year ECPD-accredited ET programs and also of four-year engineering curricula.

Goals for Engineering Technology Programs

It is emphasized that each institution when considering the development of an engineering technology curriculum should first establish a knowledgeable committee to express the goals and objectives of the program, both general and specific. This study should precede design of curricula or courses. Committee representation of faculty and administration should be supplemented from the probable sources of students and sources of employment for graduates. It is recommended that the design of engineering technology curricula, for either the associate or the baccalaureate degree, proceed from goals to detailed objectives and then to corresponding emphases upon broad subject-matter areas before these areas are broken down into required courses and electives.

Considering the several possible sources of students, the several kinds of programs, i.e., two-year, four-year, two-plus-two, co-op, evening, etc., and the possible curricular emphasis as related to employment, no two programs are likely to be identical or to have identical goals and objectives. Nevertheless, the goals expressed below are broadly applicable. They cover both associate degree and baccalaureate degree programs.

Goals for Associate Degree Programs. An associate degree engineering technology program should produce engineering technicians who understand the language of engineering, written, symbolic and graphic, and who can interpret in material terms the results of engineering analysis and design. The achievement levels in mathematics and science should be established in relation to standards of admission and to employment goals. The degree of specialization required to meet employment goals should be determined before specialized courses are designed or initiated. The non-technical content in the engineering technology program should be planned to meet predetermined objectives of communication and understanding of society which may also contribute to the upward mobility of the employed technician. The assemblage of a group of unrelated existing college courses is not envisioned. Both technical and non-technical studies should be structured to fulfill clearly stated objectives.

Goals for Baccalaureate Programs. The overall goal of a baccalaureate engineering technology curriculum will encompass most of the objectives of a strong associate degree engineering technology program, but it should exceed such objectives in several areas. It can carry the math-science sequence to a higher level, but it should not attempt to match the requirements of an engineering curriculum which would both skew its objectives and raise an unnecessary barrier to freshman enrollments and junior level transfers. The technical specialties can be advanced into the area of established procedures of design based upon prerequisite study of technical sciences and related laboratory experience. The practical goals of baccalaureate engineering technology programs are closely related to industrial production, construction, or operation and encompass improvement of processes, methods, and procedures short of new system design. If supervision of production personnel is a stated goal of the program, more than the usual attention should be given to non-technical studies designed to achieve awareness of the importance of communication, interpersonal relations and techniques of management.

Based upon the considerations outlined above, it is recommended that the following actions be considered by individual agencies related to technological education or to its graduates, including their employment and further development.

1. Communication with High School

Junior and senior high school students should become informed regarding technological education. In a response from 412 graduates of associate degree engineering technology programs, only 15 per cent gave high school teachers and counselors credit for influencing their career decisions. Improved communication should be considered by a joint committee from engineering societies enhanced by representation of educational agencies and high school administrators, teachers, and guidance counselors. The continuing objective should be to inform junior and senior high school students regarding the full range of technical careers.

2. Private Technical Institutes

The private technical institutes should continue to provide programs of high standards for associate degree engineering technicians, and continue to seek ECPD accreditation for their programs. Over the years these programs have established standards and provided examples for new institutions entering the field of engineering technology education. Those that develop four-year ET programs should provide leadership in integrating the first two years with the upper division while maintaining, to the maximum extent found to be possible, an employment outlet for graduates with the associate degree. The leadership role of private, non-profit technical institutes has been substantial in the past and will be needed in the future.

3. Public Two-Year Institutions

The public institutions which offer technically oriented education programs — including community junior colleges, vocational-technical schools, technical institutes, and centers or branches of four-year institutions — are expected to prepare a major proportion of the engineering technicians needed by industry. These institutions are also expected to provide substantial numbers of graduates who will transfer to baccalaureate technology programs at the junior-year level. These objectives should be met by design with full recognition that an engineering technology program at the associate-degree level requires advanced production-type laboratories and a faculty that includes engineers and technology graduates as instructors. Only those with rather large enrollments should undertake engineering technology programs at the associate degree level. The cost of providing both laboratories and instructors beyond the vocational level is only justified if 20-30 graduates can be produced annually from each specialized program. Because of early terminations, admission of 50-70 new students per year per program may be needed for viability.

When a vocational-technical institution undertakes to offer an associate-degree program in engineering technology, it should plan to seek ECPD accreditation or, if restricted from doing so, it should accept its responsibility to meet ECPD standards. Otherwise, the use of the adjective "engineering" in the description of the program should be avoided. Programs that do not reach the associate degree level should not be termed "engineering technology." For those institutions that do not desire to meet the standards for engineering technology, it is entirely feasible to produce less specialized technicians for industrial employment. The more competent students from such programs may then find opportunities to complete a baccalaureate degree in programs of industrial technology. Their transfer into a baccalaureate *engineering* technology program will normally require a period of prerequisite study.

4. Junior - Level Transfer

The transfer problem from several kinds of "lower division" institutions to several types of baccalaureate engineering technology programs can be handled on an individual basis or by developing a satellite system of a senior and several junior institutions. Individual transfer requires evaluation of individual courses completed, testing or a trial program. It is recommended that all of these devices be used because individuals are indeed individuals and their capacities are not entirely defined by transcripts. Students' futures should neither be limited nor endangered by automatic transfer on merely a time-enrolled basis. The satellite system gives promise of a simpler procedure of transfer, but it is unlikely to provide a channel for more than a minority of transfer students. Both baccalaureate and lower-division institutions are urged to maintain records on all transfers of technology students to improve the transfer procedure and increase the success of the experimental two-plus-two educational system. A period of planned experimentation is recommended.

5. Cooperative Technological Programs

Although little significant experience exists, it seems evident that a two-plus-three cooperative educational program should be considered where the local industrial situation is favorable. The final three years might be co-op. Such a program could provide greater educational flexibility for strengthening the lower-division background of the transfer student than a two-plus-two program. Also, the industrial experience acquired before graduation should add directly to the immediate useful-

ness of the graduate to industry because the employment of the technologist before and after graduation is likely to be with one company or industry. Co-op technology education appears very promising and is recommended for serious consideration.

6. Separate Technology Administration

The administration of engineering technology programs at the baccalaureate level should be related to the technical development of the institution involved. A major factor is the existence or non-existence of a college of engineering. If there is no college of engineering on the campus, the interest in technological education may have developed as an extension of industrial arts education into industrial technology without engineering input. An engineering related curriculum may result when evening service courses in technology, often taught by part-time engineering instructors, grow, first, into an associate degree and, finally, into a baccalaureate program. In either case, the final development of a baccalaureate technology program for full-time students will require technically competent administration and a full-time faculty with technical specializations. In a previously non-technical educational environment, it will function best as a separate administrative unit or college. However, to justify a separate administrative unit, it should first be determined that there will be a viable enrollment comparable to that recognized elsewhere in the institution by separate administration.

7. Administration with Engineering

There are successful examples of a college of technology and a college of engineering operating in parallel under separate administrations. There are equally successful examples of baccalaureate technological programs that operate as a unit within a college of engineering. It seems less probable that a single department within a college of engineering might successfully operate two parallel baccalaureate programs, one in engineering and the other in engineering technology. The desirably different admission standards for students, desirable distinctions in degrees and in experience requirements for faculty, separate accreditations, and the difference between professional and paraprofessional status of the graduates all argue against parallel programs within a single department. If the department's technology program is not strongly differentiated from its engineering program, the former will probably fail because it is then involved in producing a second-class product. Its objective should be to produce first-class engineering technologists. It is recommended that administration at the departmental level for engineering and engineering technology be separate. At the college level, the choice between separate or joint administration will be influenced by the local situation, such as size of program, extent of joint use of faculty or facilities, and the center of administrative interest.

8. Continuing Education Programs

Technologists and technicians, as well as engineers, must continuously update their knowledge through formal continuing education or independent study. It is recommended that local groups representing education, technical societies and employers form continuing education committees. They should arrange wherever possible for planned sequences of math-science-technical courses and also management studies to be provided at convenient hours on a scheduled basis. New techniques, such as taped courses, are becoming available for use in isolated locations. It is recommended that industry and government, as majority employers of technical personnel, accept greater responsibility in the future for providing means of updating and enhancing the capacities of their technical employees at all levels as an active program to counteract technological obsolescence.

7. Technical Society Responsibility

The main technical engineering societies need to face the question of possible membership for engineering technologists. A large majority of engineering technologists specialize in the same broad areas as engineers — electrical, mechanical, chemical, civil, etc. It is unlikely that the technical societies will be duplicated for service to technologists. Hence, the technologists must look to the principal engineering societies for new technical information. They will do this quite normally if some type of membership is available to them. Restricted transfer to an advanced level of membership based upon professional requirements would appear adequate to protect the engineering profession from undue dilution of professional competency. Technical societies related to a particular industry are unlikely to have membership qualifications that would be restrictive to technologists. It is recommended that engineering societies with restricted membership consider how they may extend their technical services to engineering technologists and technicians.

10. Multidisciplinary Society Service

The multidisciplinary engineering organizations, including ASEE, ECPD, EJC, and NSPE, should increase their attention to the accrediting, recognition, and service functions in relation to engineering technology. To the extent that engineering technology is recognized as a respected career closely related to the profession of engineering, both technicians and technologists should support and work effectively with engineers. Otherwise, a dichotomy could develop that would produce public confusion and that might raise problems of a legal nature.

11. Engineering Technology Accreditation

It is recommended that ECPD continue to develop its procedures for accreditation of associate degree programs in engineering technology based upon goals, definitions and distinctions included

herein. Its accreditation procedures have been reasonably successful, but an effort should be made to achieve greater coverage of the field. In particular, this will require that ECPD give more consideration to the special objectives and educational problems of the community junior colleges. At the baccalaureate level, criteria are needed that go well beyond the criteria for associate degree programs in engineering technology. Such factors as background of the faculty in education and experience, quality of the student body, library holdings, laboratory development and educational level achieved by the curriculum are all important in establishing criteria for baccalaureate programs in engineering technology. Although highly restrictive criteria are not suggested, there is strong justification for increased academic standards and reduced vocational emphasis in the junior and senior years of a baccalaureate program in engineering technology. Hence, it is recommended that one criterion be a limit upon the percentage of courses in a four-year program that are commonly available to lower-division students.

12. Industrial Technology Accreditation

No recommendation seems appropriate at this early stage of development regarding ECPD accreditation of industrial technology education. Its lower math-science-technical content and increased content of management and liberal arts or education seem unlikely to fit the curricular pattern appropriate to engineering technology accreditation. Hence, an additional accreditation procedure would be required. It is recommended that the industrial technology institutions consider whether their best interests might be served by asking ECPD to propose a separate procedure for accreditation of industrial technology education at the baccalaureate level in which they would participate in a major way.

13. Responsibilities of Various Agencies

Federal, state, and private agencies involved in the support of technical education, and agencies that represent institutional groups offering engineering technology programs, particularly at the associate degree level, carry a responsibility for the overall quality of technical education. This responsibility can be carried out effectively for engineering technology education by encouraging institutions to seek ECPD accreditation or, in lieu thereof, to equal or exceed ECPD criteria. Standards for evaluating faculty, students, physical facilities and educational level achieved by the curriculum are acceptably measurable and are all involved in specialized accreditation. It is recommended, therefore, that all agencies related to technological education take seriously their responsibilities to help educational institutions distinguish programs of engineering technology from other technological programs. In this way they will serve both students and employers as well as the general public.

14. Responsibilities of Employers

At a task force meeting of fifteen industrial representatives held at the desire of the Advisory Committee in September, 1970, interest in the employment of both associate-degree technicians and baccalaureate technologists was made manifest to the staff of the technology study. However, there was considerable variation between employers in their anticipated uses for such employees. The consensus for the manufacturing group seemed to be that engineers, technologists, and technicians might be hired for similar jobs, but that achievement and advancement would separate capacity for production management from technical orientation. It was admitted that the title "engineer" is still applied loosely by industry. Looking forward to the future when industry will doubtless be employing considerable numbers of engineering technologists and industrial technologists, as well as technicians and engineers, it is recommended to engineering employers that the use of the title "engineer" be restudied and restricted to positions requiring the background of a graduate engineer. In borderline situations, a title including engineering as an adjective would be justified, with the same general significance that it carries in the terms engineering technician, engineering technologist, and engineering technology.

15. Balancing Production Against Need

Finally, it is recommended that engineering technology programs at the baccalaureate level be initiated only where conditions are favorable and the need is established. The rapid growth of college enrollments is due to terminate in another decade. We have already seen overproduction of certain professionals who were in short supply a few years ago. The present production of baccalaureate technologists is so small that any problem of oversupply seems remote. However, it is well to balance enthusiasm for this new development with the recognition that the overall need for high level technologists cannot be measured until industry and government have had increased experience with their employment and their productive value. A gradual development of new programs with continuing evaluation of results will provide the opportunity to adjust the production of baccalaureate technology graduates to employment opportunities.

Appendix A

Industrial Technology: Excerpts from the California State Colleges Study of 1970

Engineering technology education interfaces along one boundary with engineering education and along another boundary with industrial technology education. Therefore, it is necessary to understand the current development and status of industrial technology programs and the use within industry of IT graduates in order to establish criteria for distinguishing between ET and IT educational programs. Since the ASEE study could not be extended to cover industrial technology, dependence is placed upon published material, the most comprehensive and recent study being that of the California State Colleges entitled Industrial Arts/Industrial Technology, *published February, 1970.*

The remainder of this appendix will be a series of quotations from the CSC study report, including a summary of the results of its industrial survey. A more detailed abstract was included in the Preliminary *and* Interim Reports.

Background and Definition

Although not all institutions which offer some version of industrial technology employ this particular title, it is the most common one, and appears to be gaining even wider acceptance. The formation of the National Association of Industrial Technology in 1967, as an entity separate from the American Industrial Arts Association, is a sign that industrial technology is coming of age. The "position paper" of the California Council on Industrial Arts Teacher Education (1968) characterizes today's industrial technology program as:

> . . . preparing students for such positions as those in planning, supply, product utilization and evaluation, production supervision, management, marketing research, and technical sales. These graduates are capable of analyzing problems, as well as recommending, implementing and supervising appropriate solutions. They satisfy the emerging need for technical administrators in industry.

Weber in 1961 pointed out that:

> The main difference between industrial technology and the other types of programs [i.e., industrial arts teacher education and technical institute training] is the general area of preparing students for positions in management.

... The graduate, though having knowledge of basic industrial skills, is oriented towards assisting and directing the development program, the flow of production, the distribution of the product, and other facets of general management. The technologist supervises operations involved in the development of a consumer product, or its movement to the distribution point, and even making it acceptable and popular on the open market. Some curricula offer variations in the business portion, permitting a sales emphasis, for example.

With regard to the appropriate curriculum to prepare the technologist, one Report (Dean, 1967) has stated:

> The training includes a basic knowledge of some engineering and management principles, a broad knowledge of industrial processes and the operation of machines and equipment, in addition to applied technical and practice skills. The chief asset of the training is that the graduate of such a program is provided with a broad background . . . which makes him flexible and adaptable to almost any kind of industrial organization with a reasonable amount of in-service or job orientation training.

Evolution of Industrial Technology

In the evolution of the typical industrial technology program, a pattern is discernible. Starting as a technical track or option within the established industrial arts curriculum, industrial technology is naturally heavily weighted with the only resource that is abundant: industrial arts courses. Gradually, the technical specialty, which originally consisted of one or more of the traditional industrial arts fields, yields to a focus on a "cluster" of industries, such as manufacturing, construction, and electricity/electronics, or sometimes on a job category, such as sales. The general program, characterized by great flexibility and adaptability, has passed into its most sophisticated form when the content is well-suited to the objective of preparing the technical administrator. By this time it is usually a separate curriculum leading to its own degree. At most the industrial arts portion of the curriculum consists of providing the basic skills and knowledge and contributing to the technological specialty as appropriate. . . . The breadth of preparation which is characteristic of industrial technology stems from awareness on the part of educators that they would be doing a disservice to graduates if, since technology changes at such a breathtaking pace, they trained them too specifically for skills that will be obsolete quickly.

Administration and Relation to Industrial Arts

As in the case with industrial arts, the administrative location of industrial technology programs varies from campus to campus. . . . Experts disagree over the question of whether joint or separate administration, classes, and instructors are better.

The tendency across the country, at least in the larger colleges, is for industrial technology, although it originated in and was nurtured by industrial arts, to break away and become independent at maturity. . . . Whether or not it is administered separately, industrial technology requires two or three specialized laboratories, one of them designed to give the student an overview of manufacturing processes and to demonstrate the elements of total production. Moreover, the industrial technology instructor must have extensive industrial experience and must maintain close and continual contacts with the evolving technology in industry.

Relationship to Community Colleges

Mutually beneficial arrangements have been effected, whereby the Community Colleges offer pre-baccalaureate programs expressly designed to permit the student to transfer into an industrial technology program at a particular State College without loss of time or credit. . . . Industrial technology is in many ways the "natural" advanced program for Community College technical graduates to enter. By design, the upper division part of the broadly conceived program concentrates on "rounding out" the student, and thus could yield readily to the two-plus-two approach. Picking up the student whose lower division training has been relatively specialized, preparing him for middle-level technical jobs in industry, industrial technology at the upper division can provide him with the means to quality for higher-level positions through courses in management, communications, psychology, and humanistic/social studies, among others, and through advanced and integrative technology courses which give an overview of technology and the industrial enterprise. . . .

. . . The contents of the vocational programs, dubiously collegiate-level in many instances, need to be upgraded. Many technical programs are too narrowly focused and excessively skill-oriented rather than concept oriented. A majority require no college mathematics at all, and practically no science, or at least not to any depth. Since there are few electives, the student has no opportunity to secure breadth either in general education areas or in general technology. Though students are, of course, encouraged to combine the occupational curricula with the requirements for the associate degree, there is not enough insistence on it and woeful lack of counselors with understanding to identify the better students and to channel them into transfer tracks.

Relationship to Engineering

In all the literature on industrial technology and the descriptions of programs, reference to producing semi-professional engineers is studiously avoided. . . . Of course, many graduates will actually be hired for positions that are engineering-related and will be given titles in which the term "engineer" figures prominently. Industrial technology educators can hardly be faulted for industry's tendency to ignore some academic subtleties and to use the term "engineer" loosely, especially as a means of upgrading in position.

[In definitions of engineering technology such as that of ECPD,] . . . the key phrase is *in support of the engineering effort of industry.*

On the other hand, the industrial technology faculty at Cal Poly, San Luis Obispo, describes its program as:

> . . . that part of higher education which prepares students for professional-level (baccalaureate degree) technical occupations in industry, excluding professional engineering. This field, forming the mid-ground between engineering and business administration, emphasizes the applied aspects of industrial processes and personnel leadership. It is based upon a foundation of understanding and working knowledge of industrial materials, tools, processes, procedures, and human relations.

The key phrases here are *occupying the mid-ground between engineering and business administration* and *emphasizing the applied aspects of industrial processes and personnel leadership.*

CSC Industrial Survey

Survey of Industrial Firms in California. Soon after the industrial arts-industrial technology study began, it became clear that a survey of industry was needed. Whereas a good deal of information about industrial technology programs could be gleaned from existing literature, the same could not be said of industry's viewpoint toward the general concept of an industrial technology curriculum. The present survey was restricted to firms indigenous to California or national firms with major branches in California. . . .

Analysis of Companies' Responses. Number of companies receiving questionnaire, 290; number of companies responding, 154; number completing questionnaire, 129, or 44 percent.

Type of Product	*Response*	*No. of Employees*	*Response*
Space, Aero	41%	Under 1000	37%
Chemical, Wood	34%	1000 - 4999	44%
Manufacturing	46%	5000 and over*	71%
Electronics	76%	[*Large companies hire the majority of IT graduates]	
Food	67%		

Conclusions Drawn from Questionnaire. Detailed analysis of the responses, including many correlations and refinements, revealed both a definite pattern to the responses and a remarkable degree of internal consistency. Patently, industry has a need for technologists with baccalaureate degrees, and this need will accelerate in the future. For curriculum planning and development, the most important finding is that industry is looking primarily for production-oriented persons who will eventually move into managerial and supervisory positions, and consequently technologists possessing a broad technical background combined with business and managerial techniques and communication skills are preferred.

Industry's View on Curriculum. One purpose of the Survey of Industry was to discover what industrialists consider desirable content for an industrial technology program. The following pattern emerges from the respondent's distribution of unit-time according to the six general subject areas which comprise industrial technology:

Subject Area	*Percentage of Total Program*	*Indicated Equivalents in Semester Units*
General Education	20%	25
Communication Skills	12%	15
Mathematics	12%	15
Science	13%	16
Technical Subjects	26%	32
Business Administration	17%	21
Totals	100%	124

Educational Subjects Considered Necessary or Desirable by 70% to 99% of Respondents. Starred subjects ranged from 88% upward. Companies responded as follows:

Subject	*Response*[1]
Mathematics	
*Arithmetic (College Math)	99%
*Algebra	98%
*Trigonometry	88%
Descriptive Geometry	79%
*Statistics	91%
Computer Programming	76%
Technical Studies	
*Introductory Drafting	94%
*Blueprint Reading	94%
*Basic Mfg. Processes	96%
Machine Tool Skills	81%
Tool Design	76%
*Mechanical Systems	96%
Design Mech. Systems	84%
Design Elec. Systems	79%
Strength of Materials	84%
Electrical Power	75%
Product Evaluation	80%
*Time & Motion Study	89%
*Engineering Economy	90%
*Assurance or Control	90%
Advanced Control	80%
Industrial Design	72%
Science & Applied Science	
*Physics	88%
Statics	72%
Dynamics	70%
Communications	
*Public Speaking	94%
*Technical Writing	96%
Audio Visual	73%
*Psychology	92%
Business Administration	
*Accounting Principles	98%
Marketing Principles	78%
*Human Relations	99%
*Introductory Economics	94%
Financial Management	81%
*Management Principles	98%
*Industrial Relations	95%
Customer Relations	80%
Introductory Oper. Research	76%
*Production Supervision	91%
Industrial Purchasing	87%

[1] Percentages were computed by the ASEE staff.

Positions Most Likely to be Filled by Industrial Technology Graduates. Companies suggested that Industrial Technology graduates might fill positions such as listed below:

	Nature of Position	*Responses*
(1)	Production Management	104
(2)	Purchasing	43
(3)	Quality Control	81
(4)	Sales	42
(5)	Logistics	12
(6)	Field Service	40
(7)	Job Development and Training	16
(8)	Market Research	10
(9)	Other	42

Recruitment and Hiring as Related to Curriculum. The following indications of preference by companies relate to educational background for new employees.

Preference	*Responses*[1]
a. Prefer four-year industrial technology graduates	41%
b. Prefer four-year engineering technology graduates	45%
c. Prefer four-year industrial arts graduates	4%
d. Have no preference as to type of technology graduates	7%
e. See no need for technologists to receive more than two-year preparation	3%

[1] Percentages were computed by the ASEE staff.

Appendix B

Statistical Information and Data Tables

The following tables give reasonably current data and statistics that have relevance to the ASEE Study of Engineering Technology Education. The subjects covered are enrollments and projections, associate degrees and bachelors degrees for engineering technology and industrial technology, technicians employed by industry, hiring goals, salaries and job openings.

TABLE B-1. Reports and Projections of Enrollment in Institutions of Higher Education in the United States, 1960-75.[a]

Year (Fall)	Total	Degree Programs[b]	Non-Degree Programs[c]
1960	3,789,000	3,583,000	206,000
1963	4,766,000	4,495,000	271,000
1966	6,390,000	5,885,000	505,000
1969	7,541,000	6,906,000	635,000
1972	8,686,000	7,925,000	760,000
1975	9,956,000	9,056,000	901,000

[a] Adapted from Table 4, *Projections of Educational Statistics to 1977-78*, U.S. Department of Health, Education and Welfare, Office of Education, National Center for Educational Statistics (Washington: U.S. Government Printing Office, 1969).

[b] Includes all programs leading to baccalaureate or higher degree.

[c] Includes programs of occupational nature, wherein credits are not chiefly transferable to a baccalaureate degree and which are 3 years or less in length.

TABLE B-2. Reports and Projections of Earned Bachelor's and First Professional Degrees in the United States, 1960-75[a]

Academic Year (ending)	Total Degrees	Degrees in Physical Science and Related Areas[b]	Degrees in Engineering[c]	Percentages of Total: Physical Science	Percentages of Total: Engineering
1960	392,440	29,512	37,808	7.5	9.6
1963	447,622	34,752	33,458	7.8	7.5
1966	551,040	39,764	35,815	7.2	6.5
1969	749,000	60,130	39,072	8.0	5.4
1972	785,000	68,670	40,330	8.8	5.1
1975	898,000	85,170	40,690	9.5	4.5

[a] Adapted from Tables 18 and 20A, *Projections of Educational Statistics to 1977-78*, U.S. Department of Health, Education and Welfare, Office of Education, National Center for Educational Statistics (Washington: U.S. Government Printing Office, 1969).

[b] Includes mathematics, statistics, computer science, astronomy, chemistry, earth sciences, meteorology, physics and certain general science programs; excludes the biological sciences, agriculture, forestry, and the health professions.

[c] Data for 1960-69 from the Engineering Manpower Commission: see John D. Alden, "Engineering Degrees, 1969-70," *Engineering Education*, February 1971, p. 432. This report by EMC showed 42,966 bachelor's and other first professional degrees in engineering for the 1969-70 academic year.

TABLE B-3. Associate Degrees in Engineering Technology Reported by Institutions Having at Least One Curriculum Accredited by ECPD[a]

Year	Number of Degrees Reported
1953-54	3927
1954-55	4365
1955-56	5499
1956-57	No data available
1957-58	5928
1958-59	6478
1959-60	7639
1960-61	6284
1961-62	6035
1962-63	5489
1963-64	5507
1964-65	5695
1965-66	5270
1966-67	6144
1967-68	6264
1968-69	6536
1969-70	7740

[a] Source: John D. Alden, "Technology Degrees, 1969-70, *Engineering Education*, February, 1971: see Table 1, p. 441. Data for 1953-64 were gathered by Donald C. Metz *et. al.* for ASEE. Data for 1965-66 to date were surveyed by the Engineering Manpower Commission.

TABLE B-4. Degrees Awarded in Engineering Technology and Industrial Technology, 1969-70, By Curriculum and By Level[a]

Curriculum	Associate Degrees	Bachelor's Degrees
Aircraft	722	118
Air Conditioning	194	19
Architectural	864	73
Automotive	737	133
Chemical	374	14
Civil	1784	227
Computer	1012	68
Drafting, Design	1082	93
Electrical	1629	358
Electronics	4273	654
Industrial Technology	541	1535
Manufacturing	338	104
Marine	66	7
Mechanical	2719	502
Metals, Materials	91	4
Mineral	14	2
Nuclear	66	0
Other	628	194
Total	17,134[b]	4,105

[a] Data taken from John D. Alden, "Technology Degrees, 1969-70," *Engineering Education*, February, 1971, pp. 441-46.

[b] In addition, 4,146 certificates were awarded (1,148 at institutions with ECPD-accredited curricula), for a total of 21,281 awards.

TABLE B-5. Ratio of Technicians to Engineers by Industry as Reported in 1968 by a Sample of 658 Employers[a]

Industry	Number of Technicians Employed by Respondents	Number of Technicians per 100 Engineers
Aerospace	8,306	28
Chemical	1,077	9
Construction	629	68
Consulting	2,505	58
Electrical/Electronics	6,960	69
Machinery	2,821	46
Metals	1,886	71
Other Manufacturing	6,260	38
Petroleum	435	51
R & D	5,368	68
Transportation	306	65
Utilities	4,863	66
Federal Government	2,200	41
State Government	18,332	161
Local Government	1,683	70
Education	1,345	20
All Respondents	64,976	54

[a] Adapted from Table 11, p. 20, *Demand for Engineers and Technicians, 1968*, Engineering Manpower Commission of the Engineers Joint Council, December, 1969. The sample of employers does not necessarily coincide with the samples forming the data base in Tables B-6 and B-7 of this section.

TABLE B-6. Comparison of Hiring Goals for Technicians and Number Hired, 1967-68, Reported by 852 Employers[a]

Category	Hiring Goal	Actual Hires	Shortage In Percent
4-Year Technology Graduates	323	168	48%
2-Year Technical School Grad.	3,187	2,519	20%
Other School Sources	1,473	1,338	9%
Experienced Technicians	2,885	2,571	11%
Newly Upgraded Technicians	878	870	1%
Trainees	2,647	2,556	3%

[a] Adapted from Table 17, p. 27, *Demand for Engineers and Technicians, 1968*, Engineering Manpower Commission of the Engineers Joint Council, December, 1969. The sample of employers here does not necessarily constitute the same data base as Tables B-5 and B-7 of this section.

TABLE B-7. Comparison of Hires, 1967-68, and Planned New Hires for Technicians, 1968-69, by 897 Employers[a]

Category	Hired in 1967-68	Planned for 1968-69	Planned Increase
4-Yr. Technology Graduates	231	342	48%
2-Yr. Technical School Grad.	2,482	3,269	32%
Other School Sources	1,750	1,979	13%
Experienced Technicians	3,127	3,505	12%
Newly Upgraded Technicians	1,311	1,372	4%
Trainees	2,878	3,045	6%

[a] Adapted from Table 17, p. 27, *Demand for Engineers and Technicians, 1968*, Engineering Manpower Commission of the Engineers Joint Council, December, 1969. The sample of employers does not necessarily constitute the same data base as in Tables B-5 and B-6 of this section.

TABLE B-8. Salaries for Technicians in 1969, All United States, by Educational Level and Years since Entering Work Force[a]

Years Since Graduation[b]	Mean Annual Salary		
	All Technicians[c]	Associate Degree	Bachelor's Degree[d]
0	$6,650	$ 7,100	$ 8,350
2	7,100	7,650	8,650
4	7,500	8,150	8,950
6	7,950	8,650	9,200
8	8,350	9,050	9,450
10	8,750	9,450	9,650
12	9,200	9,850	9,950
20	9,850	10,300	10,800

[a] Adapted from "General Salary Curves," pp. 18-20, *Salaries of Engineering Technicians, 1969*, Engineering Manpower Commission of the Engineers Joint Council, March, 1970.

[b] Base year is 1969. For Associate Degree recipients and non-graduates, this is considered age 20; for baccalaureate graduates, the equivalent age is 22. Year 0 represents initial salary.

[c] Includes all technicians, those with no prior formal schooling and those with educational background other than technology as well as graduate technicians.

[d] Data should be interpreted with caution. The bachelor's degrees held by the technicians covered may have been earned in areas other than engineering technology and often were earned after some years of employment; this is especially true for older individuals.

TABLE B-9. Employment of Selected Professional and Technical Personnel Employed by Reasons of Nation's Development Goals, 1966, with Projection to 1975[a]

Item	Engineers	Natural Science and Engineering Technicians
Employed in 1966	1,116,000	713,000
Projected Employment in 1975, Assuming "Low" National Priorities[b]	1,589,000	1,518,000
Projected Employment in 1975, Assuming "High" National Priorities[c]	2,031,000	1,794,000
Proportionate Increase, 1966 - 75, "Low" National Priority[b]	42%	113%
Proportionate Increase, 1966 - 75, "High" National Priority[c]	82%	152%

[a] Adapted from Table 1, Paul G. Larkin and John B. Teeple, "National Employment Goals and Higher Education," *College and University Business*, October-December, 1969.

[b] "Low" national priorities imply a continuation of the employment demands of the past decade and reflects national goals which are "more of the same" as existed in the 1960's.

[c] "High" national priorities imply bolder specific objectives and an enhanced pattern of technological and economic growth which could come about if national commitments are made to pollution control, urban redevelopment, space exploration, and other massive projects.

TABLE B-10. Employment of Technicians by Occupational Specialty, Estimated 1966 and Projected 1980 Requirements.[a]

Occupation	1966 employment	Projected 1980 requirements	Percent increase, 1966-80
Technicians, all occupations	886,900	1,395,700	57.4
Draftsmen	272,300	434,300	59.5
Engineering and physical science technicians	419,300	646,800	54.3
Engineering technicians	299,200	453,800	51.7
Chemical technicians	60,500	96,500	59.5
Physics technicians	10,600	20,700	95.3
Mathematics technicians	5,300	10,100	90.6
Other physical science technicians	43,900	65,700	49.7
Life science technicians	70,000	108,900	55.6
Other technicians	125,100	205,800	64.5

NOTE: Because of rounding, sums of individual items may not equal totals.

[a] Source: Bureau of Labor Statistics, U. S. Department of Labor. *Technician Manpower, 1966-80.* Bulletin Number 1639. (Washington, D.C.: U. S. Government Printing Office, 1970.)

TABLE B-11. Sources of Technician Manpower, 1966-1980, Estimated by the Bureau of Labor Statistics.[a]

Source of New Technicians, 1966-1980	Number
Post-secondary Pre-employment Training	750,000
Employer Training	175,000
MDTA Training	95,000
College (4-yr.) graduates and drop-outs	150,000
Armed Forces Training	21,500
Total Entrants to Field	1,191,500
Losses[b]	256,500
Net Technician Manpower	935,000

[a] Source: Bureau of Labor Statistics, U. S. Department of Labor. *Technician Manpower, 1966-80.* Bulletin Number 1639. (Washington, D.C.: U. S. Government Printing Office, 1970.)

[b] Losses include separations because of death, retirement and transfer and may result from promotion to supervisory positions within the field as well as from removals from the field.

Appendix C

Comments from Industry and Institutions Related to Technicians and Technologists

Subsequent to the publication in October, 1970, of the Preliminary Report *of ASEE's Engineering Technology Education Study, more than 200 institutions, organizations, agencies and individuals submitted formal documents containing comments, reactions, and suggestions related to the content of that report. All these documents were carefully reviewed by the Study Staff and the Advisory Committee. The comments were extremely valuable as background to this* Final Report.

Thirty quotations from the many documents received are presented here to illustrate the kinds of responses made. They were chosen largely from the responses of industrial or other employers of technical personnel.

Quotations from Respondents

1. "The report will have an important effect on colleges and universities by removing much of the confusion which now exists, both in semantics and course content." *(Lockheed Aircraft Corporation)*
2. ". . . Junior colleges are not particularly interested in accreditation. . . . Accreditation will be sought only if industry demands it and when it may be necessary for their graduates to transfer into a four-year program." *(Society of Manufacturing Engineers, Education Committee)*
3. "Strong emphasis should be placed on ECPD accreditation of baccalaureate programs, not only to distinguish those which are truly within the engineering spectrum, but also to maintain a close and appropriate tie to the engineering profession. . . ." *(University of Akron Committee)*
4. "Take a position. Keep the administration separate." *(Dow Chemical Company)*
5. "Inclusion of Engineering Technology under Engineering will prevent Engineering Technology from growing up into a competing Engineering degree on the one hand and conversely sinking to the vocational level on the other." *(Cleveland State University)*
6. "The general concept of a two-year technician program is very sound. . . . A great many tasks performed by engineers or technologists could be performed by technicians with less than the 4-year degree." *(General Mills, Inc.)*
7. "We are a degree oriented world. Credentials have a bearing on acceptance by others, thus the Bachelor's degree becomes important at times." *(Cornell, Howland, Hayes & Merryfield, Consulting Engineers)*
8. "Emphasize that with four-year programs, the stigma of limited horizons that evolved with the A.A.S. does not apply." *(General Motors Corp.)*
9. "*There are* aspects of social studies and humanities which are relevant *and interesting* to technically oriented students, but these aspects have not been properly identified and taught to students." *(Dow Chemical Company)*
10. "Concur wholeheartedly that a very significant increase in the number of technologists with a four-year degree is needed and can and will be properly employed in industry." *(Edison Electric Institute Committee)*
11. "The committee suggests clarification of the terms 'technician' and 'technologist' . . . by referring to them as graduates from four and two-year programs, respectively [sic]." *(Society of Manufacturing Engineers, Education Committee)*
12. "The Industrial Technology supporters claim a proficiency in a broader spectrum than can be achieved." *(Phillips Petroleum Company)*
13. "The possibility of revision of the engineering curricula of some schools from a theoretical to a practical orientation seems to us to have been dealt with too lightly. . . ." *(Union Carbide Company)*
14. "The Plant Engineering student should not be forced into an engineering technology program and marked as an assistant to a science-research oriented engineer that he will never see." *(American Institute of Plant Engineers)*
15. "Granted that quality is widely achieved and generally recognized, the four year Technologist will not be regarded as a 'second string' Engineer, but rather as one who has chosen his course through preference rather than necessary compromise." *(General Motors Corp.)*
16. "I was bothered . . . that the distinction [in the report] between engineering and engineering technology is associated with the responsibility, or lack thereof, to society. The words and thoughts sound fine, but I don't think they are representative of the real world." *(NASA, Lewis Research Center)*
17. "The report [should] indicate what portion of the educational preparation involves exposure to a staff that includes leaders from crafts and unions and leaders from the areas of industrial codes and standards. . . ." *(EE&A Subcommittee, ECPD)*
18. "We believe that the engineering technology faculty must be largely separate from an Engineering or an Industrial Arts faculty, must have substantial industrial experience, and, at least for the present, must be composed largely of engineers. A doctorate should not, in our opinion, be a requirement for such a faculty." *(N.Y.-N.J. Electrical Technology Association)*
19. "Why is such a four-year [B.E.T.] program needed? We have found that usually job requirements considered somewhat minor and time consuming for engineers can be adequately filled by the technician." *(Delmarva Power & Light Company)*
20. "While we have made little use of the engineering technology graduate, we foresee that he would be assigned to jobs which are involved with planning and scheduling, essentially between engineering and manufacturing. The need for technologists has long been felt and has become particularly acute as our technology has become more complex." *(Lockheed Aircraft Corporation)*
21. "There are a number of areas, particularly in manufacturing operations where the attendant responsibilities of analysis, decision, and direction provide positions for which the 4-year technology graduate would be particularly well suited. These functions would also provide graduates the opportunity to progress to management levels." *(Ford Motor Company)*
22. ". . . A very significant increase in the number of technologists with a four-year degree is needed and can and will be properly employed in industry." *(Cleveland Electric Illuminating Company)*

23. ". . . Many civil service positions in the federal government use the title technologist or technician." *(Engineering Manpower Commission)*

24. "Many in industry would be inclined to feel that using the definition of engineer in this report would in fact relegate the analytical engineer as a 'support' person to the engineering technologist who is concerned with solving the problems in an operating situation." *(Eastman Kodak Company)*

25. "Engineering Technology graduates may progress to assignments such as Specifications Engineer, Drawing Checker, Manufacturing Engineer, Product Assurance Engineer, Liaison Engineer, etc. Industrial Technology graduates might progress to similar assignments, but would perhaps be more likely to become Operations Planners, Price Estimators, Buyers, Make-or-Buy Analysts, Logistics Analysts, etc. Engineering graduates would not be excluded from any of these job families, but their interest in these occupations is not likely to be strong." *(Lockheed Missiles and Space Company)*

26. "The four year technologist is now an ideal candidate for manufacturing training. He falls midway between the Business and Engineering graduate, both of which are also aspirants for plant management positions." *(General Motors Corporation)*

27. "I would expect that as four-year engineering technology graduates become more numerous we would tend to hire these people rather than the two-year graduates." *(Proctor and Gamble)*

28. ". . . We at Armco's Research Center have much confidence in industrial technology schools as a source for technicians." *(Armco Steel Corp.)*

29. "There is need for technicians in narrow functional areas of civil engineering, but not as a broadly trained technician." *(ASCE, Education Division)*

30. "The hard, cold, practical fact is that anyone with any type of engineering education will aspire to be called an engineer, and there is not the nice, clean interface that the educators think there is between the duties of the many people engaged in an engineering-oriented program, be it design, construction, manufacturing or operations." *(Bechtel Corp.)*

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